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THE CHEAPEST POINT OF CUT-OFF.

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In reply to the criticism of Professor De Volson Wood in this journal for January, 1844, in which he asserts that the proof given in my article on Cut-off, December, 1883, lacks in generality, and "is equivalent to assuming that the constant charges *vary* with the cost of steam," I would first express my regret that Professor Wood has not given some law, equation or example, instead of dealing in general assertions. It is easy to follow and criticise; it is hard to originate.

The assumptions on which my article is based are as follows:

First. That the constant charges are dependent solely on wages, cost of oil, interest, insurance, taxes and probable deterioration of machinery, and independent of all else.

Second. That the person designing an engine knows what horse-power is expected of it.

It is true that an engine does not run with exactly the same load at all times, but an engine is never designed or bought by an intelligent mechanic without some probable average horse-power being fixed upon.

These two are the sole assumptions made, and I do not see how the problem could be attacked with fewer fixed premises.

The constant charges C are not "assumed to be a constant fraction of

the cost of steam," but may be determined regardless of the cost of steam.

Whenever it is possible to fix the constant charges on and to design an engine regardless of its horse-power, then will the proof lack in generality. Until then, we cannot reduce the number of our premises below the two stated.

To take a homely instance, John Doe finds that the wages of his engineer and fireman, the amount of oil, and repairs, are about the same per day for a 100 horse-power engine as for a 300 horse-power engine. The taxes and insurance may be slightly less in one case, but surely not enough to make any great difference. John Doe has to pay this amount (say $10 per day), no matter how he varies the power of his engine or his cut-off.

Still John Doe has no use for more than 150 horse-power on an average; all over that would go to waste, if it did not work injury.

How is he to get this 150 horse-powers for the least sum of money? There is no other answer save this: *by using the least possible steam per horse-power per hour.* Reference to my paper will make it clear, I trust, as to how the point of cut-off affects the weight of steam per horse-power per hour, and also fix the limits within which physical laws confine the expansion of steam.

If John Doe should ever require 250 horse-powers in the development of his business, he would find it cheapest to add 100 horse-power by either putting in a new engine of the required power (250), so proportioned as to cut off at the cheapest point of cut-off, or, by adding a 100 horse-power engine to the one already in (both are assumed to have the cheapest point of cut-off), without increasing his working force.

This same point was mathematically stated in my letter of Oct. 20, 1883, to the *The American Engineer*, with the remark: "If I am correct in my premises, the method of Professor Rankine, as well as the papers of Messrs. Wolff, Denton and Weightman, and of Professor Thurston must be valueless." There has been no proof, of any practical value, given to the contrary of this assertion, or of my original position in this journal, June, 1880, save such limitations as I have myself established December, 1883. It is true that John Doe, when using 250 horse-powers, *gets his power* for less per horse-power than when using only 150 in this wise.

Reckoning steam at 25 cents per thousand pounds, and a horse-power at 25 pounds of steam per hour—

For 150 horse-powers.

Wages and constant charges per day	$10 00
$150 \times 10 \times 25 = 37{,}500$, at 25 cents	9 37
Total	$19 37

Cost per horse-power per day, $12\frac{9}{15}$ cents.

For 250 horse-powers.

Wages and other constant charges	$11 00
$250 \times 10 \times 25 = 62{,}500$, at 25 cents	15 62
Total	$26 62

Cost per horse-power per day, $10\frac{6}{15}$ cents.

In either case, John Doe's only opportunity to save money lies in saving steam per horse-power per hour, and the greater the power used the more money he can save by proper attention to the point of cut-off. It is right here that these gentlemen—Professors De Volson Wood and Thurston, and Messrs. Wolff, Denton and Weightman—have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded.

It will be noted that I have made a large allowance of $1 per day to cover the increase in constant charges due to the larger size of engine required for 250 horse-powers per day.

The business ability of John Doe will appear in his selection of an engine, and his hiring of attendants, and in the other details of constant expense.

In buying an engine he must have knowledge of the mechanical and physical action of steam, but his purchase and arrangements being made he has done with the constant charges, and must look to economy of steam as the only means of saving money.

In other words, John Doe must determine the most economical point of cut-off for his particular case from purely physical considerations, and then, if he can, buy an engine which will do his work with that cut-off with the least amount of constant charges.

He will be wiser if he anticipates an increase of business to choose a cut-off a little too early rather than too late for greatest economy.

The point of cut-off has, practically, nothing to do with the constant charges, save so far as it determines the volume of the cylinder required. The cost of an engine is not proportional to the size of the cylinder but rather to the amount of labor put upon it as a whole.

Suppose John Doe, finding out that he must pay $26.62, under the most favorable circumstances for 250 horse-power per day, thinks he can arrange matters so that the constant charges will be $10 per day and the cost of steam $16.62, he has got to make this difference in the constant charges in the difference that exists in the cost of oil, interest, insurance and taxes. This difference amounts to very little in reality. As for the difference in oil, its amount is so dependent on the care of the oiler more than anything else that it should properly not be considered.

If we assume $1,000 may be saved in buying an engine less economical of steam, we might save $100 per year, reckoning interest, taxes and insurance, as collectively 10 per cent, or $200 if at 20 per cent.

This assumption is improbable, but let us see what it means at 10 per cent. The reader can follow at 20 per cent. also.

One hundred dollars per year means 32 cents a day, and therefore if John Doe does save $1,000, he has just 32 cents to put into steam, or if he could manage to save $1 per day, he would have to reduce the first cost of his engine alone by about $3,000, but then the boilers must be larger in order to furnish 4,000 lbs. more of steam per day, with equal economy of fuel, to be used in the engine with less economy.

In reality no saving could be effected, and we can safely set off against any possible saving effected by diminishing the size of the steam cylinder, the greater cost of increase, logically required in the size of the boilers.

The question of high speed or slow speed has nothing to do with the point of cut-off, and often very little with the question of first cost. It is a matter in which sound mechanical judgment or experience must appear.

I have assumed John Doe to be a manufacturer, who wishes to do that thing which at the end of a year or ten years is most profitable, and not a person cramped for capital.

The difference in deterioration of engine and boilers is neglected and the wages of engineer and fireman are assumed to be the same in both cases. Deterioration practically depends far more on the care given than anything else.

In the case of an engine already erected, the owner naturally will

hesitate, however well informed he may be, before undertaking the trouble and expense of changing his engine until a considerable excess of its cheapest power is demanded of it, and from a financial point of view be right in disregarding, to a certain extent, the saving of steam.

In these matters there is always room for good judgment, but it should be borne in mind that fuel and steam from it are disappearing all the time, and that a saving of one dollars' worth of steam per day is equivalent to a saving in first cost of plant of from $1,500 to $3,000, and therefore we are financially as well as from a physical point of view justified in neglecting the constant charges, in determining the point of cut-off.

If the reader will refer to Hann & Gener, on the steam engine, page 115 (published London, Eng., 1854), he will there find the following equation

$$\frac{a}{e} = \frac{\text{volume at pressure } P}{\text{volume at pressure } P'}$$

which is derived from the formulæ of Pambour.

In this formula, if we assume the pressures inversely as volumes, the result is the same, as that given in my paper of June, 1880, by an original method and without knowledge of their method or results.

I may, however, lay claim to having originally shown the limitations of expansion to be dependent solely upon physical causes. [The "Limitations of the Steam Engine," JOURNAL FRANKLIN INSTITUTE, August, 1880, and "The Cheapest Point of Cut-off, December, 1883.]

Also to having shown the influence of clearance and compression upon the point of cut-off (JOURNAL FRANKLIN INSTITUTE, December, 1883), and the relation probably existing between the weight of steam from boiler and the weight of steam by indicator per horse power per hour (JOURNAL FRANKLIN INSTITUTE, January, 1884). I crave the readers pardon for prolixity in such simple matters, and for a self-assertion forced upon me.

With regard to equation (5) to which Prof. Wood has taken exception, I would say that e is a function of the mean effective pressure, is so written and so used, and that shrewd and skillful mathematicians have found no ambiguity in it.

To repeat again what I have said in this journal, Dec., 1883, $C =$ the constant charges, in dollars and cents, and is assumed to remain a constant after once being fixed upon.

The proportion from which equation (5) is derived is this:

$cV : eV ::$ constant charges per day (C); cost of steam per day for a cut-off, e, and a given horse-power.

c is not a constant, as stated by Prof. Wood, nor is it said to be a constant in my paper; it is a function of the mean effective pressure.

If fallacy there be in what I have written, it must be found in the above proportion.

The question squarely at issue between myself and my critics is this:

Do the constant charges have the effect of making the cheapest point of cut-off later than it would appear to be from a purely physical consideration?

I have asserted, and believe I have proved, that they do not. I would further add that I am convinced that the ratio existing between the actual steam from boiler and the steam by the indicator diagram in no wise affects this question.

More knowledge of the law of this ratio may affect the point of cut-off, but will not involve the constant charges.

The mere assertion of so distinguished a mathematician as Prof. Wood carries so much weight that it is a duty which he owes to himself and to the writer to give the most careful consideration to the point at issue, and either prove the writer's error unmistakably, or to fairly acknowledge his own, in as public a manner as he has seen fit to publish his condemnation.

It is a question that not only involves himself, but also all his colleagues giving instruction in engineering in the Stevens Institute.

Since writing the above I have received an interesting letter from Mr. J. W. Thompson, of Salem, Ohio. His success as a practitioner has been so great as to render what he says of interest to all engineers, so I take the liberty of publishing his letter, in part:

DEAR SIR:—We heartily agree with you that some reliable experimental data are badly needed to establish a reliable scale of "unindicated loss" for different points of cut-off, other things equal; but we regret to have to say that we are unable to contribute anything of value in that direction. We have long been aware that the "cheapest," or, as we would have put it, the most economical point of cut-off was considerably later than that at which the best results could be figured theoretically from the diagram; but just where the cheapest point is, all elements of cost, including interest on investment, being taken into the account, we are willing to humbly sit at the feet of any "Gamaliel" who can inform us. In the absence of any such positive knowledge we have been content to assume that about quarter cut with steam ranging from 75 to 90 pounds cannot be far wrong; at all events,

it is not too late, and if it is too early there is this compensation, that most customers will be far better satisfied if they discover that they have slightly too much power for the best economy than if they have not enough, and then almost everybody expects to increase their business in the near future, and would rather pay slightly too much per horse-power at first than take the risk of soon being overloaded. Hence, for purely commercial reasons, there is no very urgent need for the coveted knowledge; we would not, probably, see any reason to depart from the "quarter cut" rule if we had it, except, perhaps, in cases where the duty was exactly known beforehand, and was subject to no fluctuations, and no possibility of future increase. Yet, for the sake of scientific satisfaction, and for practical use in the few cases where it could be applied, we would be much pleased to have the desired information.

From such data as can be obtained it appears that about the best that can be done under the best conditions hitherto existing when careful economic tests were being made, is to make the diagrams figure within near 90 per cent. of the actual consumption. And when such results are reached it is likely that it is due almost entirely to that unavoidable condensation of the induction steam in the cylinder by its recently refrigerated walls, a theory with which you are of course perfectly familiar. Condensation from radiation into the atmosphere can be so nearly prevented by non-conducting covering and loss from leakage can be so nearly prevented by good workmanship and attention to packing and adjustments, that the problem is reduced almost entirely to the question of inter-cylinder condensation—how much it is aggravated both absolutely and proportionately by high grades of expansion. Losses from the other causes named will not vary greatly with varying expansion, at least not proportionately, and perhaps not greatly absolutely. Hence, the more nearly the loss is confined to the unavoidable source when tests are being made, the more reliable will be the results with reference to the question under consideration.

There was formerly in our employ a young man, by name Jesse Warrington, who was something of a prodigy in the way of quick, instinctive and short-cut mathematics. Away back in the '70s, about 1874, if we mistake not, he suggested to the writer that there might be a constant figured out which, when divided by the product of the mean effective pressure and the volume of the total terminal pressure, would give the theoretical rate of water consumption, independently of any knowledge of the size and speed of the engine. Acting on the hint, I figured one out, it being obviously the consumption of water per indicated horse-power per hour of an engine subjected to one pound maximum efficient pressure, and driven by solid water instead of steam. The process was as follows: A horse-power being 33,000 foot-pounds per minute, it will be 23,760,000 inch-pounds per hour; this divided by 27·648, the number of cubic inches in a pound of water when a cubic foot weighs 62·5 pounds, gives 859,375, and I remember being somewhat struck with the singular fact that the calculation comes out exactly even, without a fraction. $\frac{33{,}000 \times 60 \times 62{\cdot}5}{144}$ also gives it.

Yours truly,

J. W. Thompson (Buckeye Engine Co.).

The rule given by Mr. Thompson was mentioned as "the usual rule" in this journal, Jan., 1884, pages 1 to 5. I am pleased to be able to give the credit to its originator.

Several typographical errors occur in the formulæ in my papers in this journal, Dec., 1883, and Jan., 1884. These can be readily detected by the skilled mathematician.

On page 4, line 7, of this journal, Jan., 1884, "clearance included" should have read, clearance not included.

AN INVESTIGATION LOCATING THE STRONGEST OF THE BRONZES.

By W. Ernest H. Jobbins, M. E.

Triple Alloys of Copper, Zinc and Tin.

General Introduction.

It is thought better to preface this report upon the investigation, conducted by the author, with a short resumé of what had previously been accomplished by MM. Wertheim and Riche, Professor R. H. Thurston, and Mr. Maurice I. Coster.

These earlier investigations furnished the foundation for the present one, the author commencing at the point to which the others had brought the work. This report is, throughout, necessarily very concise; but the results indicate clearly where the strongest alloys will be found.

The subject has been divided into five parts; each one being a separate and distinct investigation, though at the same time an effort has been made to form a continuous report. Of course, Part V is the most important portion of this report, for the previous investigations have been reported and discussed a number of times, and it is to this part especially that attention is called.

It will be seen that the "strongest alloy" has been decided upon and that the area containing the best ground for future investigation has been reduced to a minimum; and, furthermore, the conclusions arrived at from the results of earlier work in this field are confirmed by the investigations here to be described.

Part I.

Researches of Wertheim and Riche.

The following is an abstract from a "Report on the Elasticity and Tenacity of the Alloys," by M. G. Wertheim.*

"In an earlier paper which I had the honor to present to the Academy during the session of July 18th, 1842, I considered the mechanical properties of the simple metals. After having examined and compared the different methods of studying elasticity in relation to ordinary as well as to high temperatures, I applied these methods to the pure metals and obtained results of which I will describe only those which serve as the basis of this new work.

"It was made known by these experiments: 1st. That the coefficient of elasticity is not constant for the same metal, but that it changes with density and in the same way. 2d. That longitudinal and transverse vibrations indicate a coefficient of elasticity a little greater than that deduced by direct elongation. 3d. That experiment agrees with theory as to the relation which should exist between the coefficient of elasticity and the mean distance between the molecules; that is, whenever, in the same metal, this distance becomes greater, the coefficient of elasticity diminishes, and reciprocally; consequently, the different metals form the same series, whether arranged according to their coefficients of elasticity or according to the proximity of their molecules. 4th. That the product of the coefficient of elasticity by the seventh power of the mean relative distances of the molecules is the same for the greater part of the metals.

"In this second paper, which I have the honor to present to the Academy, my object is to see, first, if these laws are equally applicable to alloys; then to ascertain whether the mechanical properties can assist us to an understanding of the arrangement of the molecules of the constituent metals of the alloys; and, finally, to seek for some relations between the properties of the alloys and those of the constituent metals. The alloys, with the exception of brass and of bell-metal, have not yet been studied as to their elasticity. The cohesion of the alloys, on the contrary, has been the object of a long series of experiments, especially by Muschenbroek and Karmarsh, but as yet, no general law has been found. The alloys which I have used in my

* *Comptes Rendus*, vol. 16, 1845, pp. 978–1000.

experiments have been made, in part, of the purest metals of commerce, and, in part, of the metals employed in my former researches. After mixing them well, I stirred them frequently while in fusion, then poured them. The ductile alloys were drawn, the others filed, to the requisite size. When the alloys were composed of metals whose specific weights were very different, or when they exhibited inequalities of color or of malleability, I made analyses of parts taken from the two extremities of the cast bar; consequently, with these analyses, I was obliged to reject a large number of non-homogeneous bars. My experiments were made upon fifty-four binary alloys and nine ternary alloys, among which are found, also, most of the alloys employed in the arts. These experiments gave the following results: 1st. If we suppose all the molecules of an alloy to be the same distance from one another, as seems natural, we find that the smaller the mean distance the greater is the coefficient of elasticity. We notice frequently some exceptions in the series of alloys, and further, the product of modulus of elasticity and the seventh power of the distance of the molecules, which is almost constant for simple metals, varies greatly in the alloys. It is possible that another hypothesis of the molecular arrangement will cause this objection to disappear. 2d. The coefficients of elasticity of the alloys agree sufficiently well with the mean of the coefficient of elasticity of the constituent metals, some alloys of zinc and copper being the only exceptions. The condensations and expansions which occur during the formation of the alloy do not sensibly affect the coefficient. We can thus calculate beforehand what should be the composition of an alloy, in order that it may have a given elasticity, or that it may conduct sound with a given rapidity, provided that this elasticity or this velocity fall within the limits of the values of these quantities for the known metals. 3d. Neither the tenacity, nor the limit of elasticity, nor the maximum elongation of an alloy can be determined, *a priori*, by means of the same quantities as determined for the metals which compose them. 4th. The alloys act like the simple metals as to longitudinal and transverse vibrations, as well as elongation."

The next paper of interest is one by M. Alfred Riche, which appears in the same publication seventeen years later, and in which he remarks: "There is no study more generally neglected than that of the metallic alloys. This very general neglect is due to the fact that the characteristics upon which we rely in determining the purity of substances are

usually inapplicable to these substances. Their melting points, even, cannot be determined, either because separation takes place before they attain their highest temperatures, or because we have no precise means for determining such high temperatures."

M. Riche then goes on to prove "that the crystalline form is not a gauge of their purity," and that the precise determination of the point of melting and of solidification is often prevented by liquation. It was this latter property that enabled M. Rudberg to prove the existence of true chemical combinations among the numerous alloys of the two metals; but it can only be utilized in a few cases where the point to be determined is that of the melting of alloys at low temperatures.

M. Riche does not give, in this paper, any information about either copper-tin or copper, zinc and tin alloys, confining himself to those of tin and lead, tin and bismuth, lead and bismuth, and antimony and lead. But, in a later paper, we find the following most valuable information relating to the alloys of copper and tin, with respect to their density, liquation and fusibility:

Density.—The first determinations were made on bars weighing from 50 to 60 grammes; but such great variations were found to exist in the texture of the different alloys, that, in subsequent investigations, the materials were reduced to powder. There were great variations in the expansion of the alloys; it increased quite regularly from those rich in tin up to the alloy $SnCu^2$, and attained a maximum when the tin and copper were in the relation of 1:3.

Liquation.—In order to exhibit this characteristic the material must be stirred at the moment of solidification, in order to separate the little drops of metal from the crystals already formed. The following table shows the results obtained on the last portion left liquid in a mass weighing 1,000 to 1,200 grammes. From this it will be seen that there is no appreciable liquation in the case of the alloys $SnCu^3$ and $SnCu^4$.

Fusibility.—In making this determination, the thermo-electric couple of platinum and palladium of M. Becquerel was used by M. Riche, Weber's needle being employed instead of the ordinary galvanometer, on account of its being much more sensitive. This apparatus was made by M. Ruhmkoff. It was found that the solidification of the alloys $SnCu^3$ and $SnCu^4$ took place at a temperature intermediate between the point of fusion of antimony and the boiling point of cadmium. Liquation prevents an exact result being obtained except with

TABLE I.—*Composition of Alloys.*

Formula of Alloy.	Calculated Weight of Tin.	Weight of Tin as Found.
Sn^4Cu	90·27	98·50
Sn^3Cu	84·79	96·99
Sn^2Cu	78·79	94·40
$SnCu$	65·01	82·83
$SnCu^2$	46·49	50·42
$SnCu^3$	37·37	37·29
$SnCu^4$	31·72	31·15
$SnCu^5$	27·09	27·76
$SnCu^6$	23·09	25·17
$SnCu^7$	19·98	24·85
$SnCu^8$	18·85	24·62
$SnCu^{10}$	15·67	24·50
$SnCu^{15}$	11·00	14·35

the alloys $SnCu^2$ and $SnCu^4$, in which the liquation is insensible. M. Riche says: "I stated, as Calvert and Johnson had previously shown, that copper and tin exhibit maximum contraction in the alloy, $SnCu^3$, contrary to the opinion of other experimenters who have maintained that contraction increases with the proportion of tin."* As M. Riche worked on alloys reduced to fine powders, and the other experimenters used ingot metal, there were differences between his figures and theirs.

In regard to the fusibility of metals which melt at high temperatures, M. Riche states that he has tried various methods of making this determination, and that the only one that can be practically applied is that of the thermo-electric pyrometer, formed by the junction of wires of platinum and palladium; but as I have not had the time to enter into this part of the work in my own investigation, I shall not stop to describe M. Riche's experiments. As for his results relating to the density of the alloys of copper and tin, they verify the known fact that copper and tin contract in uniting. Still, when the proportion of the tin is very high the reverse seems to take place, but the difference is very slight. It is an understood fact that the contrac-

* Briche, Traité de Chemie de M. Dumas, tome iii, p. 512.

tion is very slight and regular up to the alloy $SnCu^2$; that, from this point, it increases suddenly till it reaches a maximum, when the copper and tin are in the relation of 3:1. Beginning with the alloy $SnCu^3$, the density first diminishes and then increases quite regularly; but the density of the alloys richer in copper, as cannon bronze, is inferior to that of the alloy $SnCu^3$, which, however, contains only 61·79 per cent. of copper. While all the preceding have the grey line of tin, and while those that follow are white or yellow, this alone is distinguished by a bluish color. It exhibits no liquation, for after four successive fusions the last solidified product possessed the composition that it had immediately after the first casting. Consequently the alloy $SnCu^3$ is, in the series of alloys of copper and tin, what the alloy Ag^3Cu^4 is in the series of alloys of copper and of silver.* The hardness increases from tin to the alloy containing copper and tin in the relation of their equivalents. From this alloy up to that which corresponds to the formula $SuCu^5$ the metal is too brittle to be assayed.

Part II.

Research of Professor R. H. Thurston.

The following is a resumé of a part of the valuable work performed by Prof. R. H. Thurston as "Chairman of the Committee appointed by the U. S. Board appointed to test Iron, Steel and other metals," confining this second part of this paper to his study of the alloys of copper and tin.

In 1879 a "Report on a Preliminary Investigation of the Properties of the Copper-Tin Alloys" was made by the "committee appointed by the U. S. Board appointed to test Iron, Steel and other metals," Prof. R. H. Thurston, chairman. This committee determined the strength, ductility, resilience, and other mechanical properties of the alloys of copper-tin cast in the form of bars 28 inches long and 1 inch square in section, prepared from the best commercial metals, but without special precaution, ordinary care being taken only to obtain good castings; the intention having been to make a later study of pure alloys. It was desired to learn, besides the properties of each particular alloy, the laws which connected these properties with the proportions of the component metals, and also whether alloys mixed in the simple proportions of

* Annales de Chemie et de Phys., 3d série, tome xxxvi, p. 193.

the chemical equivalents of the component metals possessed any advantage over other mixtures. Two series of these alloys were made, the first consisting of twenty-nine bars, of which twenty-three were mixtures of the metals in atomic proportions, four were mixtures made without regard to the atomic proportions, and the remaining two were a bar of copper and a bar of tin each without admixture. The second series comprised twenty bars, ranging from 97·5 per cent. copper and 2·5 per cent. tin to 97.5 tin and 2·5 copper, with a regular difference of composition between consecutive bars of 5 per cent. In addition to these alloys, a few other bars of cast copper were made and one of cast tin. The metal for each bar was weighed with the greatest care in the Physical Laboratory of the Stevens Institute of Technology on a balance made by Messrs. Saxton & Bache for the U. S. Bureau of Weights and Measures. The metal weighed out for each bar was 4·5 kilogrammes and the weighing was made in all cases to within one-tenth of a gramme, the balance being sensible to a very much smaller weight. The error in weighing was less than 0·00005 of the whole. The principal observer was Mr. Wm. Kent. The bars were cast with equal care, in some cases being recast two or three times in order to obtain a perfect casting. Chemical analyses of these bars were made and a table was then formed showing the variation of weight occurring during the operation of casting. These pieces were then brought to the desired form and size and subjected to transverse stress, to tensile stress, to torsional stress, and finally to stress by compression.

From the results of these tests the following conclusions were arrived at: That the relation which the variation of composition bears to the percentage of copper and tin in the original mixture does not follow any regular law dependent upon the proportions of the metals. In general, there appears to be a greater loss of tin than of copper in the bars which contain the greater percentage of copper, and a greater loss of copper than of tin in the bars which contain the larger percentage of tin, and that the bars which contain about equal amounts of the two metals show great tendency to liquation.

In the alloys which contain less than 35 per cent. of tin by original mixture, there is a greater loss of tin than of copper, with but three exceptions. In the alloys containing more than 70 per cent. of tin there is a greater loss of copper than of tin, with only one exception. In all of the alloys of these two classes, the extreme variation, of a single analysis, from the original mixture is 3·6 per cent., and gene-

rally it is less than one per cent. In the alloys between these limits, or those containing between 35 and 70 per cent. of tin, there are some bars which show great liquation and others which show very little. The plotted curve at this portion of the series is consequently very irregular and fails to indicate any definite law. It only seems to show that, in these compositions, there is a great tendency to liquation, which may or may not take place, according as certain precautions are or are not observed in casting. In the bars of which analyses showed a great amount of liquation, it was uniformly the case that the upper part of the bar contained the larger percentage of copper, and from the appearance of the fractures of different portions, from the variations in hardness and in other properties, as well as from some analyses and determinations of densities made of different portions of the bar, it appears that there was a regular increase in percentage of copper from the bottom to the top, and that there was no distinct plane of separation between two different, but definite, compositions. In two cases the difference in composition of the top and bottom of the bar amounted to more than 20 per cent. In two cases there appeared to be lateral liquation, or separation of the metals in such a manner that the exterior of the bar contained a less amount of tin than the interior. The first of these (38·37 copper, 61·32 tin) contained, by original mixture, 39·20 copper, 60·80 tin.

The analyses of the turnings from the tension-pieces, from the top and from the bottom of the bar—the turnings being taken from the whole length of the cylindrical portions of the test-pieces, and including all of the metal in the square portion of the bar, except the cylinder in the centre, 0·798 inch in diameter—gave almost precisely the same results (43·36 copper, 56·40 tin), showing a loss of tin of more than 4 per cent. A piece from the middle of the bar was then analyzed, the whole of the square section being turned into chips. The analysis of this piece gave 38·37 copper, 61·32 tin, or 0·52 per cent. more tin than the original mixture. The other bar showed the same result. The original mixture was 34·95 copper, 65·05 tin, and the analyses of the turnings from the outside of the bars at top and bottom were 40·32 copper, 59·46 tin; 40·24 copper and 59·44 tin. The analysis of a piece from the middle of the bar gave 34·22 copper, 65·80 tin.

Specific Gravity.—There is a certain degree of regularity in the specific gravities, showing that the densities follow a definite law. The densities of the castings were much lower than those of the metals as

given by other authorities. The densities would have been higher had they been determined in the shape of fine powder or metal perfectly free from minute cavities. Those bars which gave less strength than might be expected from their composition, and whose resistances to stress are rejected from the table of averages, also had lower specific gravities than those metals of nearly similar compositions which had greater strength. From a comparison of the strength of the bars, containing less than 20 per cent. of tin, with their densities, it is apparent that the strength and density are in a certain degree dependent upon each other; that is, that the greater the density of an alloy of any given composition, containing less than 20 per cent. of tin, the greater the strength. This has been plainly shown in experiments by several authorities on gun-metal, which uniformly exhibits an increase of strength with an increase of density. This fact will also account for the much lower strength of the alloy 90 per cent. copper, 10 per cent. tin, and of metals of nearly similar composition, than is given by some authorities as the strength of gun-metal. It must be remembered that the casting of small bars, such as have been used in the experiments herein described, is especially unfavorable to the production of metal of great density, while in the casting of guns and of other large masses the pressure of molten metal is much greater, and all conditions favor the increase of density.

It appears probable that the actual specific gravities of all alloys containing less than 25 per cent. of tin, do not greatly vary from 8·95, and that the specific gravity of castings of these alloys will be less than 8·95 according to their degree of porosity. Riche gives figures showing the increase of density of several alloys by tempering and compression. The specific gravity of an alloy of 94 per cent. copper, 6 per cent. tin, was increased from 8·541 to 8·939 by repeated tempering and rolling. The specific gravity as determined from pieces of the castings, are more valuable than if they were determined only from turnings, for the reason that they show the cause of imperfections in strength and other qualities, and indicate that the proper method of improving the strength is to increase the density. They also indicate that the lower the specific gravity of one of the alloys, which shows a certain definite strength, the greater increase may probably be given to that strength by any means which will cause the specific gravity to approach the figures 8·95.

The several methods of increasing the specific gravity of these

alloys, and thereby increasing the strength, yet remain to be experimented upon. It is well known that rolling, hammering, or compressing the porous and ductile metals increases their density. Casting under pressure has the same effect, as is shown in the greater density of the bottom of a heavy gun casting than the top, or the sinking head, and, in a still more marked degree, by experiments which have recently been made of casting under heavy hydraulic pressure. It is probable also that temperature of pouring and rate of cooling have an important influence upon the density, and that the use of any fluxes which may remove occluded gases from the molten metal will be likely to increase the specific gravity.

The maximum density of the series is given by the alloy (composed of copper 62·31, tin 37·35, by analysis), the original mixture of which corresponded to the formula $SnCu^3$, and it is nearly approached by the alloy 62·42 copper, 37·48 tin. The figures are 8·970 and 8·956. The specific gravity of the same alloy, according to Calvert and Johnson, is 8·954. From the first of these to the end of the series, or, to pure tin, there is an almost perfectly regular decrease of specific gravity, that of tin being 7·293, which figure agrees with the results of several other authorities. From the regularity of this decrease of specific gravity, and from the fact that all the results between the alloy containing 62·31 copper, 37·35 tin, and pure tin agree closely with the figures given by other authorities for the specific gravities of the same alloys; it also appears that these alloys are much less apt to vary in their densities than those containing less than 25 per cent. of tin, and that they have but little, if any, porosity.

Comparison of Resistances.—By inspection of the curves of comparison of strength by tensile and torsional stress, it will be seen that the curves agree very closely. From the curves of tensional and torsional strengths, it is seen that the strengths of the alloys at the copper end of the series increase rapidly with the addition of tin, until about 4 per cent. of tin is reached. The further increase up to the alloy containing about 17½ per cent. of tin, is very irregular. As this irregularity corresponds to the irregularity in the same portion of the curve of specific gravity, it is probably due to porosity of the metal, and might possibly be removed by any means which would make the castings more compact. The maximum points of these two curves is reached at the same point, viz., at the alloy containing 82·70 copper, 17·34 tin. From the point of maximum strength, the curves drop very rapidly

to the alloys containing about 27·5 per cent. of tin, and then more slowly to 37·5 per cent., at which point the minimum, or nearly the minimum, strength of tin is reached. The alloys of minimum strength are found from 37·5 per cent. tin to 52·5 per cent. tin; the observations being somewhat irregular between these points, making it difficult to state the exact minimum points of the curve, but all agreeing in showing great weakness. The absolute minimum is probably about 45 per cent. tin. From 52·5 per cent. of tin to about 77·5 per cent. of tin, there is a rather slow and irregular increase in strength to the point which has been called the second maximum. From 77·5 per cent. tin to the end of the series, pure tin, the strength slowly and somewhat irregularly decreases. The second minimum being reached at the end of the curve. It will be noticed that the irregularity of the torsion curve is much less than that of the other curves, which is probably due to the fact that in the torsional tests, the time occupied in making the test was very uniform, and also that the torsional curve is made from the average results of, usually, four tests of each bar, while the tensile tests were but two in number from each bar. One of the most important facts to be learned from the curves is that all the alloys containing more than 25 per cent. tin are practically worthless for all purposes where strength is required, the average strength of these alloys being only about one-sixth of the average of those containing less than 25 per cent. of tin.

Comparison of Ductility.—The ductility follows a very regular law depending upon the composition. The ductility by torsional tests is determined from the extension of the exterior fibre or line of particles in a torsion-piece one inch long, in parts of an inch, which is calculated from the angle of torsion given by the autographic strain diagram. This gives a correct comparison of the relative ductility of all the pieces tested, whether very brittle, or very ductile. The maximum angle of torsion given is 556·75 degrees, which corresponds to an extension of 2·1975 inches of a line of particles, originally one inch long, on a cylinder $\frac{5}{8}$ inch in diameter, on the supposition that the diameter and length of the cylinder while being twisted remained unchanged. The minimum angle of torsion is 0·4 degree, which corresponds to an extension of only 0·000006 inch. The ductility of tin being therefore more than 200,000 times that of the most brittle alloy.

Total Resilience.—The resilience or amount of work done in breaking any specimen is measured in the same manner as mechanical work

of any kind, that is, by the product of a resistance into the distance through which the resistance acts. When the resistance is variable, the work is the product of the mean resistance into that distance. The work done in breaking a piece of metal by torsional stress is the mean resistance of the specimen, as measured by the mean ordinate of the autographic strain diagram, expressed in foot-pounds of torsional moment, or pounds acting at the radius of one foot multiplied by the distance through which this moment is exerted, as measured by the total abscissa of the diagram and reduced to feet, traversed by the resistance. The torsional resistance has been calculated from the area of the autographic strain-diagram in the manner above stated, the total resilience up to the breaking point being taken in each case and reduced to foot-pounds of work. The resilience bears a very close relation to the ductility. The maximum torsional resilience is given by a bar composed of 96·06 copper, 3·76 tin, which was one of the most ductile of the stronger alloys. From the bar which gave the maximum total resilience of 599·96 foot-pounds, there is a rapid decrease to the bar, 76·64 copper and 23·24 tin, which had a resilience of only 3·72 foot-pounds. From this bar to one containing 35·85 copper, 73·80 tin, all bars, with one exception, show a total resilience by torsion of less than one foot-pound each, the minimum being only 0·08 foot-pounds, or only about 0·0001333 part of the maximum. From this bar to that containing 0·32 copper, 99·46 tin, there is a gradual increase of the total resilience to 125·99 foot-pounds, which is the "second maximum" point of the curve.

Limit of Elasticity.—The limit of elasticity has been defined as the point at which the distortion begins to increase in a more rapidly increasing ratio than the force which causes the distortion. It corresponds nearly with the point of first appreciable set, or permanent distortion. In the autographic diagrams of torsional stress, it is the point at which the curve begins (usually suddenly) to change its direction and deflect towards the horizontal. We find that, in the stronger alloys, those containing less that 17·5 per cent. of tin, the elastic limit under torsional stress is reached at from about 35 to 40 per cent. of the breaking load. As the percentage of tin is increased beyond 17·5 per cent., the ratio of elastic limit to ultimate strength is increased, the alloy 76·64 copper, 23·24 tin, giving the ratio 100 per cent.; *i. e.*, the elastic limit was not reached until fracture took place. The same result is given by all the alloys from this point to that containing 38·87 cop-

per, 61·32 tin. From this point to pure tin, the elastic limit is reached before fracture. As we deal only with the results obtained by torsional tests it is not necessary to follow Prof. Thurston's researches further, as his moduli of elasticity were calculated from the deflections obtained in the transverse tests. It may simply be stated, in passing, that the figures and curves show great irregularity, but not greater than might have been expected.

The moduli of elasticity by the transverse stress, in the alloys containing less than 24 per cent. tin was about 14,000,000. From 25 per cent. to 35 per cent. it was about 15,641,866. From 35 to 75 per cent. there was a great irregularity, much greater than that of any other property. From the alloys containing 70 per cent. tin, to pure tin, the moduli again become a little more regular, but still vary very greatly, the tendency being to decrease as the tin increases.

Before passing to the consideration of the triple alloys, we will notice the work performed by M. Riche upon the copper zinc alloys; we shall then have the results of alloying copper and tin and copper and zinc and shall be in a better position to take up the subject of the copper, tin and zinc alloys.

Alloys of Copper and Zinc.—Says M. Riche: "The zinc which I used had been purified by two distillations in the laboratory of the 'Société de la Vieille Montague,' which generously placed it at my disposal. I undertook the study of the various physical properties of these bodies, as of copper and tin, but I was obliged to give up the examination of fusibility and liquation, because the place where I had specially prepared for this work, at the mint, was not left at my disposal. The hardness increases from the alloy 90 per cent. copper to that which contains equal weights of copper and of zinc, Zn Cu. The alloy $Zn^3 Cu^2$ and the alloy $Zn^2 Cu$ are extremely fragile and break at the first shock, and the others, containing more zinc, crack after a few blows. The density was determined, first, of some ingots weighing from 60 to 100 grammes, then, on account of the greatly differing texture of these alloys, filings of them were operated upon with the greatest possible care. But it is difficult even by a sustained vacuum, to eliminate all the bubbles of air, and I was afraid to heat the filings several times in water in order to secure the expulsion of the air, because water is attacked by zinc, and all the alloys rich in this metal; and, lastly, the volatility of zinc makes it difficult to prepare the alloys in exactly atomic proportions. We find that the contraction of the

two metals in these alloys is considerable from the second, Zn^4 Cu, to the sixth, Zn^2 Cu^3. It seems to be at its maximum in the neighborhood of the alloy Zn^3 Cu^2, which is also remarkably like the preceding, in that it possesses none of the physical and mechanical properties which are utilized in the metals used in the arts. They are eminently crystalline and fragile, and appear to be in the series of these alloys what the alloys Sn Cu^3 and Sn Cu^4 are in the alloys of copper and tin. The theoretical density has been calculated with the number 7·20 found by me to be the average of four concordant determinations on metallic zinc."

Part III.

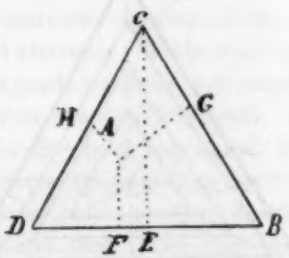
Thurston on Copper-Tin-Zinc Alloys.

We will now take up the work performed under the direction of Prof. Thurston, at the Stevens Institute of Technology, upon the triple alloys of copper, zinc and tin.

In performing this work Prof. Thurston was led to devise a method of planning this research and a system of recording data that has since led to the discovery of alloys of probably the maximum strength obtainable by any combination of the elements studied. The following is an abstract of the report:

In any equilateral triangle, *BCD*, Fig. 1, let full perpendiculars

Fig. 1.



form the vertices to the opposite sides, as, for example, *CE*. From any point within the triangle, *A*, let full perpendiculars *AG*, *AH*, *AF* and draw *AB*, *AC*, *AD*, to the vertices, thus obtaining three triangles, *ABD*, *ABC*, *ACD*; their sum is equal to the area of the whole figure *BCD*.

Now we have, since the triangle is equilateral, and $\frac{CE \times BD}{2} = \frac{AF \times BD}{2} + \frac{AG \times BC}{2} + \frac{AH \times CD}{2}$, $CE \times BD = (AF + AG + AH)\ BD$ and $CE = AF + AG + AH$, which are true wherever the point A may be situated; it is true for every point in the whole area BCD. Assuming the vertical CE to be divided into 100 parts, $AF + AH + AG = 100$, and these measure on this scale the relation of each of the altitudes of the small triangles to that of the large one. But we may now conceive the large triangle to represent a triple alloy of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and $BCD = 100$ per cent. or $CE = 100$ per cent., and the altitude of each small triangle measures the percentage of one of the three elements which enter that alloy which is identified by the point. Thus every possible alloy is represented by some one point in the triangle BCD, and every point represents and identifies a single alloy, and only that. The vertices B, C, D, in the case to be here considered, represent, respectively, copper = 100, tin = 100, zinc = 100.

Thus, having invented a method of studying all possible combinations, Prof. Thurston next prepared to examine this field of work

FIG. 2.

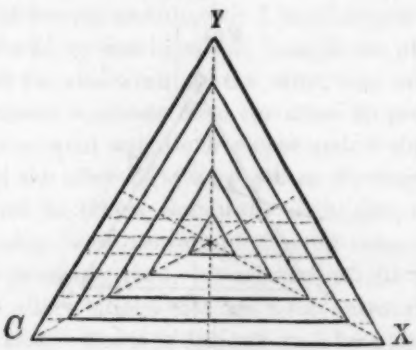


Fig. 2.

in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some

law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view the triangle laid down to represent this research was laid off into concentric triangles, Fig. 2, varying in altitude by an equal amount—10 per cent.—on which was laid out the proposed series of alloys.* These alloys were first all tested in the Autographic Recording Testing Machine, and their strain-diagrams were carefully studied. It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30 and zinc = 0, to the point copper = 40, tin = 0 and zinc = 60, were too soft or too brittle and weak to be of value.

(To be continued.)

Sensitive Thermometer.—M. Govi has presented to the Naples Academy of Sciences an ebonite thermometer supporting a capillary glass tube. This apparatus, when filled with mercury, does not show any slow elevation or diminution of temperature, but in rapid variations of heat a curious phenomenon is produced. If the temperature increases suddenly, the mercury descends in the tube and then slowly returns to the primitive level. The inverse phenomenon is produced in case of sudden cooling. The explanation is very simple, and depends upon the approximate equality of the coefficients of cubic dilatation in ebonite and mercury. When the increase of temperature is rapid, the recipient expands suddenly and alone, consequently there is a fall of the mercury in the capillary tube. The ebonite, being a bad conductor, transmits the heat only slowly to the mercury, which requires some time to resume its primitive level. A sudden impression of cold rapidly contracts the ebonite, which crowds the mercury into the capillary tube and thus raises the level. This experiment shows the importance of paying attention to the expansion of the recipient, in reading thermometric indications.—*Les Mondes*, March 17, 1883. C.

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* For this table see Report by Prof. Thurston, read before the Amer. Soc. C. E., Jan. 5, 1881, p. 4, the Strongest of the Bronzes.

WATER-LINE DEFENCE AND GUN-SHIELDS FOR CRUISERS.

By N. B. CLARK, Passed Assistant Engineer, U. S. N.

[From the Proceedings of the U. S. Naval Institute; revised and considerably enlarged by the author for publication in the JOURNAL.]

(Concluded from page 36.)

At the instance of Chief Constructor Theodore D. Wilson, who appreciates the superior merits of the curved shield, the Honorable Secretary of the Navy caused a modified form of it to be adopted in the plans for the cruiser *Chicago*. The plans for the *Boston* and *Atlanta* still contain the plane-sided shield.

The flat, under-water, armored deck applied to the *Comus* class of the British navy is in no sense a deflecting shield, as it cannot be struck by shot, being intended merely to resist the more direct downward impact of the fragments of shell, exploding within the vessel, above it. The *Comus* deck has no more curve than is given an ordinary deck for drainage, and it is so far below the water line that it does not give the room under it for boilers and machinery, which the curve, rising above the water line, affords; and, for the same reason, it does not give the margin of buoyancy which would keep the ship afloat in the absence of water-excluding stores.

The plane shield is a foreign modification of the curve, having been applied to the *Leander* class of the British navy as late as 1880; while the curved shield is a domestic product, having been designed by the writer of this article more than twenty years ago, when serving in Farragut's squadron; and was the result of observation of the effect of shot on vessels in actual combat.

Figure 9 represents a cross section of a cruising vessel of 48 feet beam and 19 feet mean draught, in which the water-line is defended by means of the curved deflecting shield No. 2, heretofore described, in combination with water-tight compartments above it to be packed with coal or stores, to augment the deflecting efficiency and exclude water, thereby serving as a life-belt to the vessel.

The cross section shown represents the compartments above the curved shield as packed with coal. The position of the curved shield in relation to the water-line is to be adjusted before going into action, by the admission of water to the double bottom. The cellular sides

of the vessel *BB*, between the curved shield *A* and the gun deck above it, are represented as packed with cotton, chemically prepared to resist fire, which would, by its elasticity, close shot-holes and exclude water.

Figure 10 represents the curves of reserve and decreased buoyancy, for the purpose of showing that a vessel having a curved deflecting shield, rising slightly above the water-line amidships, and having water-tight compartments above it packed with coal or stores, covering and protecting the under-water body, could have the sides of the vessel above the shield completely open to the sea, without destroying her buoyancy.

Figure 11 represents a cross section of a cruiser fitted with a deflecting shield rising one foot above the water-line amidships, and attached to the sides four feet below it.

We will now suppose the sides of the vessel to be shot through, allowing water to enter into all of the compartments comprising the space *GTR* over the shield, in which water-tight compartments coal and stores are packed, capable of occupying three-fourths the volume.

The water flowing in fills up the other fourth of the space *GWT*—which is interstitial—and when it has risen as high as the load water-line *WT*, the decreased buoyancy reaches a maximum equal to the weight of water filling one-fourth the space *WGT*, as shown on the curve by the ordinate *AO*. As the vessel sinks and the water continues rising in the life-belt of the ship—that is, the space above the water-line and the curved shield—the stores in the life-belt displace a volume of water equal to three-fourths the space above the load water-line and the curved shield; combining this increase of buoyancy with the decrease of buoyancy due to the water which has entered the space *WGT*, we obtain the curve *AD*, whose ordinate will represent the loss of buoyancy due to the entering water. As the vessel sinks, however, the curved shield is constantly increasing the displacement, and the ordinates of the curve *OB* will represent the increased buoyancy due to this increase of displacement. This curve intersects the former curve at *I*, at which point the upward and downward forces are again in equilibrium, and the abscissa corresponding to the ordinate at *I* will give the distance the vessel will sink by having her sides perforated completely above the shield, allowing water to enter freely all the compartments of the life-belt of the vessel. This abscissa is $2\frac{5}{6}''$, and

the vessel cannot sink further without the curved shield being pierced, allowing water to enter below it.

In comparing the plane shield, having inclined sides, with the curved shield, the relative structural strength of the two should not be lost sight of. In the curved shield, strengtened by curved beams and having the space over the shield and the berth deck divided by bulkheads, greater lateral and transverse strength can be given a ship than can be attained in any other way.

We will next consider the most desirable forms and arrangements for deflecting shields for guns. These are not simply shields, but are in fact armored gun-carriages, the guns being supported and trained upon them. Referring to Fig. 9, *C* represents a cross section of a vertical V gun-shield closed at the rear, with a 10½-inch wire wound pivot gun mounted on it *en barbette*. Fig. 12 represents a plain view of the same gun and shield.

This gun-shield is to be constructed of steel plates curved to the form shown on the plan view Fig. 12, and disposed vertically to deflect sidewise shot that come from the direction in which the gun is trained. The gun has no lateral motion of its own independent of the shield, consequently when the gun is trained to deliver its fire, the shield is at the same time trained to the most favorable position to deflect shot coming from that direction, the angle presented to the line of fire being very accute.

The gun is mounted by trunnions on a compact metal carriage, resting on slides bolted to the sides of the shield. The recoil is received on hydraulic buffers. The amount of recoil allowed for is three feet, which is ample. The top of the shield, except a space at the breech of the gun, is covered by plating of two inches thickness.

The vertical armor is formed of two thicknesses of steel plating; one enveloping the entire shield is of five inches thickness, and is reinforced at the forward end of the shield, where the angle is greatest, by an inner plating of three inches thickness. The two layers of plating form a shield of eight inches thickness, which at the acute angle presented will be impossible to penetrate with any gun now in use. These shields would be improved by constructing them of taper plates of single thickness, the greatest thickness being placed at the forward part of shield where the angle is greatest; thereby equalizing the resistance of the shield.

The shield and gun are mounted on a deflecting turn-table of eleven

feet eight inches, diamer, the outer edge of which is shaped like a double convex lens; the office of which is to protect deflectively the conical, anti-friction rollers upon which the shield rests. This lens-shaped turn-table is composed of two parts, being divided by a horizontal and a vertical line, as shown by *C* on the cross section drawing, Fig. 9.

The lower plate *D* of the deflecting turn-table is secured to the deck of the vessel, and in it are fixed the conical, anti-friction rollers upon which the shield rotates. The metal of the lower plate, immediately under the rollers, is cut away, in order to prevent an accumulation of sand or dirt which might clog them. The outer edge of the upper plate *F* embraces the lower plate *D*, thereby giving it a firm lateral support. So that no inordinate strain would be thrown upon the rotating pipe *E* by the rolling of the vessel, or the shield being struck by projectiles.

The lower plate *D* has a circular aperture in the centre through which rises the rotating and conduit pipe *E* from beneath the curved shield *A*, protecting the water-line.

The pipe *E* is secured to the upper plate *F* of the deflecting turn-table, which in turn is secured to, and forms a part of, the bottom of the shield. Consequently when the pipe *E* is turned, the shield and gun, on the deck above, are turned with it.

The shield and gun are trained by a pair of pneumatic engines *G*; pneumatic engines are preferred to steam on account of the exhaust exercising a cooling and ventilating influence. An endless screw on the shaft of the engines engages in a worm wheel secured to the end of the rotating pipe *E*, thereby turning the pipe, shield and gun in either direction with facility.

The pneumatic engines *G* are fitted with link-motion valve gear, with the lever *H* controlling it inside the shield, at the breech of the gun, convenient to the hand of the captain thereof, who trains the gun and shield by the lever without the intervention of any other person.

The lever is so arranged that when it is in the position *a*, the valves of the rotating engines are thrown into position to train the gun and shield in one direction; when in the position *b*, the valves are closed and the shield stationary, and when in the position *c*, the valves will be thrown open to train the gun and shield in the opposite direction.

This training apparatus has great power, there is therefore but little

danger of the shield being jammed fast by any obstruction. It will also hold the gun and shield firmly in any desired position, notwithstanding the rolling of the vessel.

Referring to Fig. 9, *I* represents a cross section of the pipe by which the shield is trained, which also serves as a conduit for ammunition into the shield. This pipe is V shaped, as shown by the cross section, the object being to present acute deflecting surfaces to projectiles which might strike it. It will be seen that in all positions of the shield and gun the conduit pipe *I* presents a constantly open passage to the magazines, beneath the curved shield, protecting the water-line.

The ammunition is passed up through the pipe *I* by means of the traveler *K*, which, in the drawing, shows a cartridge upon it; when it reaches the top of the pipe, inside the shield, it falls over into a little truck *L* ready to receive it. The traveler *K* is actuated by means of the crank *O*. The truck *L* is drawn out to the breech of the gun with the ammunition upon it, traversing the long arm of the lever *M*. The long and short arms of this lever are attached to a rock-shaft; the short arm is also attached to the connecting rod of a small hydraulic cylinder *N*, by means of which the ammunition is elevated to the breech of the gun upon the truck at the end of the long arm of the lever, as shown in the drawing. The loading lever *M* when in position to receive ammunition from the conduit pipe is upon the floor of the shield.

The space between the shield and the gun, when the latter is elevated is kept closed to exclude machine gun missiles, by means of the port stopper *P*, pivoted to the shield directly under the gun, against which it is pressed by means of the spring *Q*, or a counter-weight, thereby closing the space between the shield and gun occasioned by the elevation thereof.

These pivot gun-shields, while in action, should be kept trained so as to deflect projectiles even though the gun be not in use.

There is ample room in the pivot gun-shield for six men, while three men with the special appliances proposed can work the 10½″ gun with facility and efficiency.

The total weight of the pivot gun-shield with the deflecting turntable, rotating pipe, rotating engines, elevating and loading apparatus, etc., is 65 tons and 20 pounds. But if the shield was made open at the rear it would weigh much less.

The weight could also be greatly decreased by making a shield of

less thickness of plating, which would still give a very efficient protection.

The plating of the shield, shown and described, is 8 inches thick, sufficient at the very acute angle presented, if constructed of homogeneous steel, combining hardness with toughness, to deflect projectiles from any gun in extence.

Figure 13 represents a plan view of a vertical V shield of the broadside battery, the gun being trained at right angles to the keel of the vessel. Fig. 14 represents a plan view of a similar vertical V shield, open at the rear, in which the gun is represented as being trained parallel with the side of the vessel. The cross section of these V shield for broadside battery are represented by *RR* in the cross section of the ship, Fig. 9. These V shields are mounted in bay-window like projections, which, however, do not extend beyond the line of the ship's side at the water-line, the vessel having considerable tumble home.

Broadside guns, mounted in this manner, can be trained so as to deliver fire almost directly ahead or astern.

These small V shields for the broadside guns are trained in the same manner as the large pivot gun-shield, being fitted with the same appliances, and mounted on a deflecting turn-table of similar form, and in addition are pivotted in the *I* beams of the deck above. The guns, however, are not mounted *en barbette*, but extend directly through the shields.

It is proposed to partition off the upper part of the shield by means of metallic diaphragm, forming a compartment in the upper part for the accommodation of the gun-captain, who is to recline in a prone position; the diaphragm upon which he rests being well padded on each side to deaden concussion. From this position the gun-captain can see through the aperture *S* in the forward end of the shield, and can train his gun by means of the lever, controlling the valve gear of the rotating engines, beneath the curved shield. By the aid of these appliances three men, completely under cover, can load and fire a six-inch rifled gun with far greater rapidity and efficiency than a much larger number of men, exposed upon the open deck, working guns mounted in the ordinary manner.

In view of the great improvements recently made in machine guns of large size, firing percussion shell capable of piercing the sides of unarmored vessels at considerable ranges, it will be seen that a ship

having her gun-crews protected in shields of this form will possess an advantage so great that it would doubtless be good policy to have fewer guns, so protected, than a greater number unprotected. In other words, the weight of the battery should be divided between guns and gun-shields, the weight of ammunition remaining the same. The armor of the broadside gun-shields is four inches at the forward end where the angle is greatest, and two inches at the rear end where the angle is very acute.

The weight of the broadside gun-shields of four inches thickness of armor, with the deflecting turn-table, rotating pipe, rotating engines, elevating apparatus, etc., is 10 tons 760 pounds. But such a shield will give an efficient protection against the projectiles of heavy guns, while a shield of but little more than one-third the weight would give protection against heavy machine gun fire, as well as against splinters, fragments of shell, etc., which occasion nine-tenths of the casualties; a small proportion are due to exposure of men in the direct path of large projectiles. The form of the vertical V shields affords protection to the gunners within them against the side splash of splinters, and the spread of fragments of exploding shell, thus securing a great advantage over vertical armor, or guns mounted in a large casemate, as splinters and debris could devastate the interior of such a casemate from end to end, while light shields, which would offer no substantial resistance to heavy shot, would afford complete protection against splinters and fragments of shell; the protection obtained in this case against injury from shot by the subdivision of space being analogous to the protection afforded in the direction of buoyancy and stability, by the division of the underwater body into water-tight compartments.

Figure 15 represents a cross section elevation of a vertical V gun-shield, with an 8-inch rifled gun mounted on it *en barbette*, Fig. 16 is the plan view of the same. These figures illustrate the proposed method of mounting the pivot guns in the new cruising vessels. This shield is intended to be trained and the gun operated in the same manner as those heretofore described, being fitted with the same appliances; and they permit of the guns being fired either directly ahead or directly astern. As it is open at the rear end, it can be made of a proportionally less weight than the pivot gun-shield heretofore described. The plating is disposed in two layers; the outer one enveloping the entire shield is of three inches thickness, this is reinforced at the forward end, where the angle is greatest, by an inner plating of

two inches thickness, making a total thickness of five inches. The best method however for the construction of such shields would be by taper plates of single thickness.

The weight of this gun-shield with the deflecting turn-table, rotating engines, rotating pipes, loading apparatus, etc., is 32 tons 18lbs., the weight of the shield itself being 18 tons, but shields of much less weight can be constructed which will give a substantial resistance.

If the deflecting turn-tables, upon which the vertical V shields rest, were supported above the wooden deck on short drums or cylinders of sheet metal a foot or fifteen inches high, which would give an efficient support, while affording no material resistance to shot, being easily penetrable, but very difficult to cut entirely away, the danger of the shield being jammed fast by shot tearing up the wooden deck would be entirely obviated.

The vertical V shields were also recommended for the new ships by the Act of Congress providing for their construction, and they are also well adapted for land fortifications.

In considering the merits of these gun-shields, it should be remembered that the special appliances proposed will enable the guns of a ship to be operated with a much smaller crew; and, if the weight of the extra men required to work the guns by the present system, with all their belongings, and the provisions and water to sustain them, was credited to the shields, it would balance a large percentage of the weight entailed by them.

It will be seen that the armor of the proposed vessel is to be so arranged as to present no direct resistance to shot, but all the vital and offensive parts are covered by armor which protects deflectively, and the areas of the cross sections of armor are reduced to a minimum in order to present the least possible target to shot.

Projectiles are permitted to pass freely through the vessel, on the principle that the less resistance offered, the less injury received. Shot entering the side of the vessel would plow through the coal or stores packed in compartments above the curved shield, and would be deflected upward, that being the line of the least resistance, and would pass out through the far side of the vessel considerably above the water line.

As the men working the guns are all protected in appropriate deflecting shields, the upward flight of projectiles, after impinging on the curved shield, would not do any serious damage. Even though the

upper works of the ship were riddled, she would not be seriously damaged, as her vitals would remain intact.

As the crown of the curved shield rises above the water line, it thereby protects the vital far side of the vessel, where heavy shell would otherwise do the greatest damage by exploding against the frames at, and below, the water line and tearing off entire plates, thereby admitting such great volumes of water as to engulf a vessel at once.

The five vital factors of a war-ship are the water-line, the magazine, the motive power, the steering gear, and the personnel. In the proposed vessel, the first four of these and a part of the fifth are protected beneath the curved shield, the remainder of the personnel being protected in the deflecting gun-shields on the decks above.

In designing the machinery for a cruising war-ship it should be remembered that the requirements of such a vessel are entirely different from those of a passenger or fast freight steamer. The merchant steamer needs sustained high speed, with economy of fuel, to enable her to make her trips from port to port in the least possible time, and at the least expense, in order to pay a profit to her owners. The cruiser does not need sustained high speed, which can only be obtained with economy of fuel by great weight of machinery, but requires a still higher rate of speed, for short periods of time, in an emergency, when chasing an enemy or escaping from a superior force; and as this high rate of speed would be but seldom exercised, it is not admissible to carry a great weight of machinery in order to develope it with economy, and when exercised the cost of fuel would be a secondary consideration; on the other hand, it is absolutely necessary for the cruiser to be able to steam great distances, at a low rate of speed, with great economy of fuel, thereby enabling her to remain at sea for lengthened periods of time; but this low rate of speed cannot be economically developed by the machinery usually designed for sustained high speed.

According to the able and interesting report of Passed Assistant Engineer John A. Tobin, U. S. N., published as House Ex. Doc. 48, of the second Session of the Forty-seventh Congress, the average weight of the steam machinery of British merchant steamers is 480 pounds per indicated horse-power, and that of the light cruiser *Iris* is 289 pounds; and the average of the ships of the British navy is 360 pounds per horse-power, while that of the torpedo ram *Polyphemus* is 180 pounds, and of the two classes of swift torpedo boats the weight

of the steam machinery is only 57·7 and 66·5 pounds per indicated horse-power.

This remarkable reduction of weight is accomplished by the use of the locomotive tubular boiler, with air-tight fire-room and forced draught, furnishing steam of high pressure to very light machinery, constructed of steel and bronze, which transmits great power by its celerity of movement. The machinery is designed on what may be called the emergency principle.

Besides the *Polyphemus*, the cruisers recently constructed for the Chinese and Chilian governments have been engined partly on the emergency plan, the boiler being of the locomotive type, with air-tight fire rooms and forced draught, and have proved remarkably successful ships.

The steam machinery of the cruiser *Chicago* is to weigh 937 tons, and is to develope 5,000 indicated horses' power; this would give 419 pounds per horse-power. The steam machinery of the *Boston* and *Atlanta*, 3,000-ton cruisers, is to weigh 700 tons, and to develope 3,500 horses' power, which would give 448 pounds per horse-power.

If the 3,000-ton cruisers are taken as an illustration, it can be shown that the adoption of emergency power would permit of a reduction in the weight of machinery of 150 tons, which could be applied to give additional shield protection, and the attainment of an emergency speed of 18 knots per hour, with great economy of passage power; as when running at the lower rate of speed, a part of the engine power could be disconnected from the propelling instruments, thereby avoiding the loss from friction and radiation involved by an amount of machinery in excess of the power developed.

This feature would be an improvement on any vessel yet constructed and could be applied by gearing the crank shafts of vertical cylinder direct acting engines, to the shafts of twin screws, one compound engine being applied to the crank-shaft forward of, and the other aft of the driving pinion, with a disconnecting coupling on the crank-shaft for each, so that either, or both of the double cylinder compound engines could be used for driving the ship. A vessel of 3,000 tons displacement should have a central longitudinal bulkhead, dividing the under water body into two main comparments, which would be subdivided by athwartship bulkheads. Each screw would be driven by two separate, vertical-cylinder, direct-acting compound engines, the cylinders being placed close up against the central longitudinal bulk-

head in their respective compartments, in order to obtain the greatest available height under the crown of the curved shield, which would rise one foot above the water-line. Then if the crank-shafts were placed as low down as possible, there would be ample room under such a curved shield in the 3,000 ton ships for vertical-cylinder, direct acting engines of 36 inches stroke of piston, with connecting rods of 7 feet 3 inches in length.

Such engines geared down so as to make about two revolutions for each turn of the screw, designed to combine lightness with strength, like those of the torpedo boats, furnished with steam of high pressure, generated in locomotive tubular boilers, with air-tight fire-rooms, and forced draught, and having a piston speed of about 1,000 feet per minute—making about 165 revolutions per minute—thereby transmitting great power by very light machinery, by its rapidity of movement could easily develop the emergency power required within the limits of weight proposed, with great economy of passage power.

When running at a low rate of speed only one compound engine would be used to drive each screw, one engine being disconnected, thereby avoiding the loss from friction and radiation incident to running a greater amount of machinery, than is due to the power developed. When running at emergency speed, of course all the engines would be used to drive the ship. Such a form of machinery, would also be a great safeguard against accidents, as well as a source of economy when running at low speed, as the ship could be run, should occasion require, by any one of the four compound engines, and could not be totally disabled until all four engines, or their connections were broken down.

A thousand feet per minute may seem a very high piston speed, but some of the new torpedo boats having engines of 16 inches stroke of piston, make 480 turns of engine and screw per minute—there being no gearing—which is a piston speed of 1,280 feet. It should be remembered that the high emergency power would be but rarely called into action, and then for only a few hours at a time; it should, therefore, be classed with the battery as a weapon of war, never to be used except in an emergency.

It may be objected that with such extreme high power the coal supply would not last for more than four days continuous steaming; and, in reply it may be stated that the ordinary complement of ammunition would be exhausted by less than two hours rapid and continuous

firing. Under ordinary circumstances in time of peace the high emergency power would never be exerted, except for exercise or drill, in order to give the officers and men skill in its use when occasion required.

As the power necessary to drive a ship varies as the cube of her speed, and as it is estimated 3,500 horses' power will give the 3,000-ton ship a speed of 15 knots, therefore as $15^3 : 18^3 :: 3{,}500 : 6{,}045$ horses' power, which with 550 tons of machinery would give 203 pounds per horse-power.

I am well aware it may be objected, the rule of the cubes might not hold good for so high a speed as 18 knots, but the margin between 57·7 and 203 pounds in the weight of machinery would far more than cover any discrepancy which could arise from that or any other cause. The British ship *Iris* having a displacement of 3,735 tons, made 18·587 knots per hour on the measured mile, with an indicated horse-power of 7,556; and the sister ship *Mercury* made 18·87 with a development of 7,514 horse-power. See "War-Ships and Navies of the World," by Chief Engineer J. W. King, U. S. Navy.

The 150 tons additional shield protection would permit of an excellent defense of the water-line, and admit of all the guns being mounted in the single gun turrets, or deflecting V shields, giving a substantial protection against the fire of heavy guns. According to the present designs, the guns' crews of the three new ships would be almost entirely exposed, as the guns are to be mounted in vertical cylindrical half turrets of only *two inches thickness of plating, presenting a direct resistance, three feet high, and open at the top,* with a light mantlet over the breech end of the gun, as a protection against light machine gun fire; such a disposition of armor is simply futile; a gun exposed in that way cannot be fought, and a gun that cannot be worked had better be left on shore. The same weight properly disposed would give both the water-line and guns' crews a fair measure of protection against the fire of heavy guns, but with the present disposition, it will simply encumber a ship with the weight of armor without giving her the benefit of its protection.

The vessels of 3,000 tons displacement now building—although provided with airtight fire rooms and forced draught—owing to badly disposed armor, ponderous machinery, and single screws, will not be equal in power of battery, speed, handiness, or sea endurance to the vessels of only 1,350 tons displacement constructed by Sir William Armstrong & Co. for the Chinese government; as those vessels each

carry two 26-ton ten-inch calibre guns, mounted on central pivots, one forward, and one aft, commanding a nearly all round fire. The charge of these guns is 180 pounds of powder, weight of projectile 400 pounds, and will penetrate 18 inches of solid iron armor. They carry in each, besides four 40-pounders, two 9-pounders, two Nordenfelts, and four Gatlings; and furthermore, they each carry two steam cutters fitted with spar torpedoes, and are fitted with knife rams, which their remarkable manœuvring qualities renders a formidable weapon. Such a battery is far superior to that proposed for the 3,000 ton cruisers consisting of two 8-inch guns, six 6-inch guns, and six machine guns.

The weight of the broadside of the Chinese cruiser of 1,350 tons, omitting the machine guns, is 988 pounds; while the weight of that proposed for the 3,000 ton cruisers would be 800 pounds, with far greater armor-penetrating power for the battery of the 1,350 ton ship.

At the trial trips of these Chinese vessels, "with all weights aboard one attained a speed of over 16 knots per hour, and the other 16 knots, while they developed remarkable manœuvering power. After going ahead at full speed, when the engines were stopped, the ship was brought to a stop in $3\frac{1}{2}$ lengths. With the engines reversed they were stopped in about $1\frac{1}{2}$ lengths. And with one engine going ahead and the other astern, they circled rapidly within their own length."

It is almost needless to say that no such handiness could be obtained from a vessel propelled by a single screw; nor anything like the speed from the 3,000 ton ships. (For description of Chinese cruisers see "The British Navy," by Sir Thomas Brassey, K. C. B., vol. 1, page 547.) The horse-power of these Chinese cruisers is 2,600, or 1·92 horses' power per ton of displacement; while the proposed 3,000 ton cruisers are to have 3,500 horses power, or 1·16 per ton of displacement. These vessels of 1,350 displacement carry 300 tons of coal, which will enable them to steam continuously for 28 days at 8 knots per hour; while the proposed 3,000 ton cruiser will carry 500 tons of coal, which will enable her to steam 27 days at the same rate. It will therefore be seen that the Chinese cruisers of 1,350 tons displacement, are superior to the proposed 3,000 ton ships in all the points enumerated, and it can also be shown that these smaller vessels, besides being more efficient, would cost far less for construction, and after maintenance.

Although the Chinese cruisers are superior to the proposed 3,000 ton ships, they are defective in having the crowns of their curved

shields, for the defense of the water line, placed so low, as to give no margin of buoyancy in the absence of water excluding stores when the sides of the vessel are penetrated, admitting water into the vessel above the shield, thereby sinking her. It may be urged that as the stores are used the ship would be lightened, and the crown raised, so as to exclude water; this is true, but as the crown is raised, so likewise are the submerged edges, and as such a lightened vessel rolled, she would expose her sides to penetration by projectiles below the shield. It will therefore be seen that the only alternative is to give the vessel by means of the shield a margin of buoyancy above the water-line, and to trim for action by admitting water to the cellular bottom; which will also give stability of gun platform to the ship.

These Chinese vessels also have all their guns mounted on the open deck—except, perhaps, light mantlets over the breech ends of the guns, as a protection against light machine gun fire—now, no matter what the size of a gun, it is not of any use, unless it can be worked, and no gun can be worked on the open deck, if opposed by a battery of Hotchkiss revolving cannon mounted in the light vertical V shields of only two tons weight, of the type described and illustrated in this article. If half the weight of the guns was put into such shields, it would be a great improvement.

The Chinese cruisers are also defective in being fitted with horizontal engines, as such a form of steam machinery occasions greater loss from friction, wears out more rapidly, and is more difficult to keep in repair than the vertical type. The vertical cylinder engine is the only form that should ever be put into a screw ship.

If the plans of the 3,000 ton cruisers *Boston* and *Atlanta* were modified in accordance with the designs herein advocated, including adequate water-line, and gun-shield protection, with emergency power engines, they would produce vessels not only superior to the Chinese cruisers, but ships having sufficient defensive and offensive powers as to enable them to successfully contend with armor clads of much greater displacement, combined with higher emergency speed, and greater sea endurance, which would give them great value as commerce destroyers.

If it is considered more desirable to retain the same speed, and construct vessels of greater defensive and offensive powers by giving the 3,000 ton cruisers only 3,500 horse-power as is now proposed, the weight of such steam machinery on the emergency plan basis of 203 pounds per indicated horse-power, would be 321 tons, 1,460 pounds,

leaving 378 tons, 780 pounds of the 700 tons now allowed for steam machinery, for increasing the defensive and offensive powers of the ship.

This 378 tons saved from steam machinery by the adoption of the emergency principle, if put into heavy guns and deflective armor judiciously disposed, would produce a vessel which could contend successfully with any armor clad now in existence. Or this weight could be distributed to increase the defensive, offensive, and motive powers.

If the 3,000 ton ships were supplied with petroleum for fuel in time of war, it would increase their sea endurance threefold, and enable them to steam continuously at 7 knots per hour, for 120 days, during which time they could traverse 19,160 nautical miles. This great sea endurance, with the great factor of safety in their steam machinery, by its division into four separate compound engines, any one of which could be used for driving the ship, should the others be disabled, would make the vessel entirely independent of sail power.

Besides the three vessels before mentioned, provided with shield protection, the Naval Advisory Board has designed a fourth, of 1,500 tons displacement, having no shield protection, in which defensive and offensive power are intentionally sacrificed to lightness and and speed. This vessel, to be called the *Dolphin*, is to be armed with a single 6-inch gun, mounted on the open deck, and four machine guns mounted in direct resistance shields. The boilers will be partly above the water-line, and the engines will project 11 feet 6 inches above it. This ship is intended for an armed dispatch vessel. The British Government has recently constructed two vessels, the *Iris* and the *Mercury*, for similar service, but the steam machinery of those vessels is protected by being entirely below the water-line.

The *Dolphin* is now building, and the Naval Advisory Board, in a letter addressed to the Honorable Secretary of the Navy, dated October 25, 1883, has recommended that another similar vessel be constructed next year; claiming that such vessels would be very useful for the performance of the multifarious duties of general cruising, survey, and exploration, etc., in time of peace, and as commerce destroyers in time of war.

There is no question but that the *Dolphin* would make a very successful *war-vessel in time of peace*, and, if we were building a *peace navy*, her type would do very well; but if, while serving as a commerce destroyer in time of war, she should unfortunately meet an

armed vessel of the enemy of less size, similar to the Chinese cruisers, she would simply have to haul down her flag, for she would not have the power of battery to fight, nor the speed to run away.

In event of war, any desirable number of commerce destroyers, equally as efficient as the *Dolphin*, could easily be improvised, by making slight modifications to our coastwise steamers, while fighting ships cannot be improvised, but require to be laboriously constructed for that special purpose, involving a considerable period of time. Therefore it is certainly poor policy to expend any part of the small appropriatons obtainable for the increase of the Navy, while it is in its present weak condition, for any other purpose than the construction of fighting ships.

Instead of first designing a combination of hull and shield which would give the greatest measure of protection to the greatest interior space, with the least weight of armor, and then placing a suitable form of engines within that space, the board seem to have first determined upon the type and dimensions of the engines, and then to have built the ships around them.

The machinery of all four ships is either exposed above, or so disposed below the water-line as to vitiate any benefit to be obtained from shield protection. In the twin screw cruiser *Chicago* the ends of the beams of the anomalous engines project so far toward the sides as only to be covered by a shield presenting an angle of 27° to horizontal fire, which with 1½ inches of plating is a mere travesty on protection. In the *Boston* and *Atlanta*, the engines, being horizontal, do not interfere, but the boilers project out so far as to require a shield of 28°, which with 1½ inches thickness of plating is simply futile; and in the *Dolphin*, a war-ship designed *for service "in time of peace,"* the engines themselves project 11 feet 6 inches above the water-line.

It will be understood by every practical mechanic, or other person of ordinary intelligence and common-sense, that there is no need whatever for this exposure of the machinery above, or improper disposition of it below the water-line; for the small vertical cylinder rapid-moving engines herein described, which are analogous to those which produce such marvelous speed for the torpedo boats, geared down to the revolutions of the screw, can be worked and completely protected under the crown of a curved shield of a vessel of only 6 feet draught. with the crown of the shield rising 1 foot above the water-line. Of course a vessel of such very light draught would not have a double

bottom, but when a double bottom is used there would be no objections to recessing the small driving pinion, and cranks into it, in order to increase the height for the small vertical direct acting engines.

In this connection it may be well to state that to gear a screw up, in order to make it turn faster than the engine, requires very heavy machinery, while to gear it down, as proposed, may be accomplished by very light machinery.

The locomotive type of boiler will also go under the curved shields of the lightest draught vessels.

It may be objected that the locomotive boiler is not one of great endurance, that it is not the form best suited for use on shipboard. To this it may be answered, as the power necessary to drive a ship 18 knots is 8 times as great as that needed to drive her 9 knots, which speed would not be exceeded except on rare occasions, therefore sufficient boiler power of the ordinary type could easily be carried to develope the passage power, with a very slight increase in weight, while the emergency power would be obtained from steam generated in the much lighter locomotive type.

If geared engines should be objected to there is room under the curved shield of the 3,000 ton ship for vertical-cylinder, direct-acting engines of short stroke; or for what would probably be still better, vertical-cylinder engines, set up close against the central longitudinal bulk-head, in order to obtain the greatest vertical height, with vibrating bell-crank levers; by such a type of engines a length of stroke of five feet could be obtained.

As the steam machinery of the first class torpedo boats weighs but 57·7 pounds per indicated horse-power, the difference between that weight and 419 pounds in the *Chicago*, and 448 pounds in the *Boston* and *Atlanta*, seems to be a high price to pay for the *economy* of fuel to be obtained by its use on rare occasions, for short periods of time, particularly when we consider this ponderous machinery itself has to be carried at the high speed, and that additional power has to be applied to overcome the resistance due to the displacement incident to its weight.

Besides, it should be remembered, this heavy machinery, if properly proportioned for sustained high speed, could not be run with economy at the low rate of speed at which a war-vessel consumes by far the greater part of her coal. The new ships are designed to effect economy in the consumption of one-twentieth part of the fuel—that used

at high speed—and for wasteful extravagance in the consumption of the remaining nineteen-twentieths; and are handicapped with an enormous weight to produce this result. It will therefore be seen that true economy is obtained by the use of the light rapid-working engines, which type has of late years been found to give the greatest measure of economy on shore, where the problem is not complicated by displacement, resistance and space.

I do not propose to construct steam machinery for cruising vessels on a basis of 57·7 pounds per indicated horse-power, but to take 550 tons of the 700 allowed for the machinery of 3,000-ton cruisers *Boston* and *Atlanta*, and with it to give them sufficient power to drive them 18 knots per hour; and if it required 6,045 horse-power to attain that speed, it would allow 203 pounds per horse-power. The 150 tons saved from machinery would permit of an adequate defence for the water-line, heavier guns, and when mounted in the single-gun turrets, or V shields, of a very large measure of protection for the few men necessary to work these guns, even against the fire of guns of equal power.

In reply to some severe criticisms by the London *Engineer* on the Naval Advisory Board, and the ships it has designed, the secretary of the board replies that the same statements "condemn five of the most approved new British cruisers, which are substantially of the same description as to protection, weight of battery, thickness of deck," etc. This assertion is not correct; but admitting, for the sake of argument, that it was strictly so, would that be sufficient excuse for the board to inflict similarly worthless vessels upon the American navy? If the board had authority to construct a ram is it to be understood they would copy the British *Polyphemus?*

The Admiralty modified the excellent plan of deflective ram, designed by Rear-Admiral Ammen, U. S. N., until, by various improvements—one of which was the securing of three hundred tons of cast iron on her bottom, to be dropped into the sea to ensure her buoyancy if she should spring a leak—they produced the *Polyphemus*, a complete failure; and they seem to have improved the curved deflective shield, until they produced that of the *Leander*,—this, however, has been termed "the development of armor"—and now the board, by a further improvement in the same direction, by adding six or eight degrees to the horizontal angle of incidence, have produced the shield of the *Boston* and *Atlanta*.

Our navy, at the present time, is in a truly deplorable condition, consisting as it does almost entirely of obsolete wooden ships, and still more obsolete guns. With the present range of improved rifled guns, the projectiles of some of which weigh as much as a ton, the four important cities of New York, Boston, Portsmouth and Norfolk could be shelled from the open sea, by armor clads laying in twenty-four feet of water. These four cities are designated because they each have a national navy yard in close proximity to their centres of population, and it would be the duty of the admiral commanding any hostile fleet sent against us, to destroy these naval stations, and from the unsteady platform of a vessel at sea it would be impossile to prevent shell from dropping around a radius of several miles from the point aimed at. This would, no doubt, be the excuse for laying the wealthy cities of New York and Boston under heavy contribution. Aside from the direct loss, the indirect loss from panic, depreciation in values, and disturbance of business would be enormous, far more than enough to build twenty small navies such as we require. And it must not be supposed the entire loss would fall upon the seaboard; if the exit through the port of New York or San Francisco was stopped by a single foreign armor clad for only twenty-four hours, what effect would it have on the values of the western products, corn, wheat flour, and pork, and of the cotton of the south? Twenty-four hours blockade would occasion a financial revulsion, inflicting a greater loss on the business community than the cost of twenty navies. It would touch the pocket nerve of every producer in the country.

At the present time our entire coast, including some of its chief cities, of enormous wealth, is entirely at the mercy of any third rate naval power which happens to possess two or three modern armored vessels. The present condition of our navy simply invites attack.

It has been asserted that we could defend our coast with torpedoes, but those who are competent to judge of such a matter knows that torpedoes are only an adjunct, very useful, in fact indispensable, but that the unit of force is the gun-bearing vessel, from under whose fire torpedoes can be most effectively used, and by which an enemy can be pursued, destroyed, or captured; and the scene of combat removed from our own firesides.

The plan contemplates quite an inexpensive navy, which should commend it to economists, it is based on the simple laws and practices of mechanics, with nothing abstruse or complicated about it, and

should therefore be supported by people of common sense; and it proposes to construct ships and not coffins, a feature which should commend it to the favor of every professional seafaring man.

Some of the foreign armored vessels now building cost from four to five million dollars each, while no vessel built upon this plan need cost more than one million, and the great majority not more than half that sum; and very efficient ships can be produced, fully armed and equipped at a cost of $300,000.

When it is considered that any vessel, no matter what her size, can be completely wrecked by a well directed torpedo, and that the larger the vessel the greater the danger of such a calamity, the folly of building such unwieldy ships, and the wisdom of constructing the smaller and cheaper ones, on the plan herein proposed, will be appreciated.

Every State, county, city, township, and borough in the land, maintains officers, at great expense, to protect persons and property, and enforce the laws against evil doers; and as there is probably almost as much moral depravity in the conduct of nations as there is in that of individuals, it is absolutely necessary to maintain an armed force, for the protection of property on, and adjacent to the sea.

Last year Congress appropriated $1,300,000 for the reconstruction of the navy, assuming that the country contains 54,000,000 people, this would be but $2\frac{4}{10}$ cents each; surely not an extravagant expenditure.

It has been asserted that, in event of war, our adversaries, whoever they might be could purchase some of the swift transatlantic steamers, and with them destroy our coastwise commerce, which is perfectly true, but such improvised war ships, even if armed with heavy guns, would not dare attack a regularly constructed war ship, if designed upon the plan herein advocated, for it would be feasable to construct such a vessel, even upon so small a displacement as 1,000 or 1,500 tons, with an emergency speed by which they could be run down, and then by firing single the forward pivot gun into the stern on a line with the keel, the engines projecting far above the water line would be disabled; or, if that should fail, such a ship could be easily be disabled by running the projecting ram of the pursuing vessel into the track of the propeller, which would be stripped of its blades by its own revolving power, then circling around the disabled vessel to a position abeam, a threat to ram would bring down her flag.

Owing to their defenceless water-lines it would be impossible to keep any one of the four new ships afloat in action under the fire of modern

guns; and as there is not a gun on any one of them which could be fired in action, if opposed by a battery of machine guns of 1½ inches calibre, mounted in V shields of two tons weight each, it is quite feasible to construct a vessel of the same speed and displacement as the *Dolphin*, engined on the emergency plan, and armed with two 10-inch pivot rifles, and a battery of 1½ inch machine guns mounted in V shields, which would be more than a match for all four of the new ships combined.

ELECTRO-PLATING WITH NICKEL.

By WILLIAM H. WAHL.

[A paper read before the Chemical Section of the Franklin Institute, Nov. 6, 1883.]

Nickel-plating is an American industry, in the sense that it was first successfully practised on the commercial scale in the United States, and here received that practical demonstration of its usefulness that has since made it the most successful and most widely practised branch of the art of electro-plating. Coming first into prominence and popularity about ten years ago, it has since that time rapidly grown, until to-day it has developed into an industry of great magnitude. The almost silvery whiteness and admirable brilliancy of electro-deposited nickel; its cheapness as compared with silver; the hardness of the electro-deposited metal, which gives the coating great power to resist wear and abrasion; the fact that it is not blackened by the action of sulphurous vapors which rapidly tarnish silver; and the circumstance that it exhibits but little tendency to oxidize even in the presence of moisture, are sufficient to explain the great popularity which nickel-plating enjoys.

The industrial development of the art, however, which has been surprising both in respect to its rapidity and extent, may be attributed in a large measure, to certain favoring circumstances, quite independent of the excellent adaptability of the metal for electro-plating purposes. These circumstances are: first, the great advances that have been made within the period above named, in the production of nickel on the commercial scale, by which the cost of the metal has been greatly reduced, and its purity greatly increased, for which we are indebted largely to the American Nickel Works of Camden, N. J.,

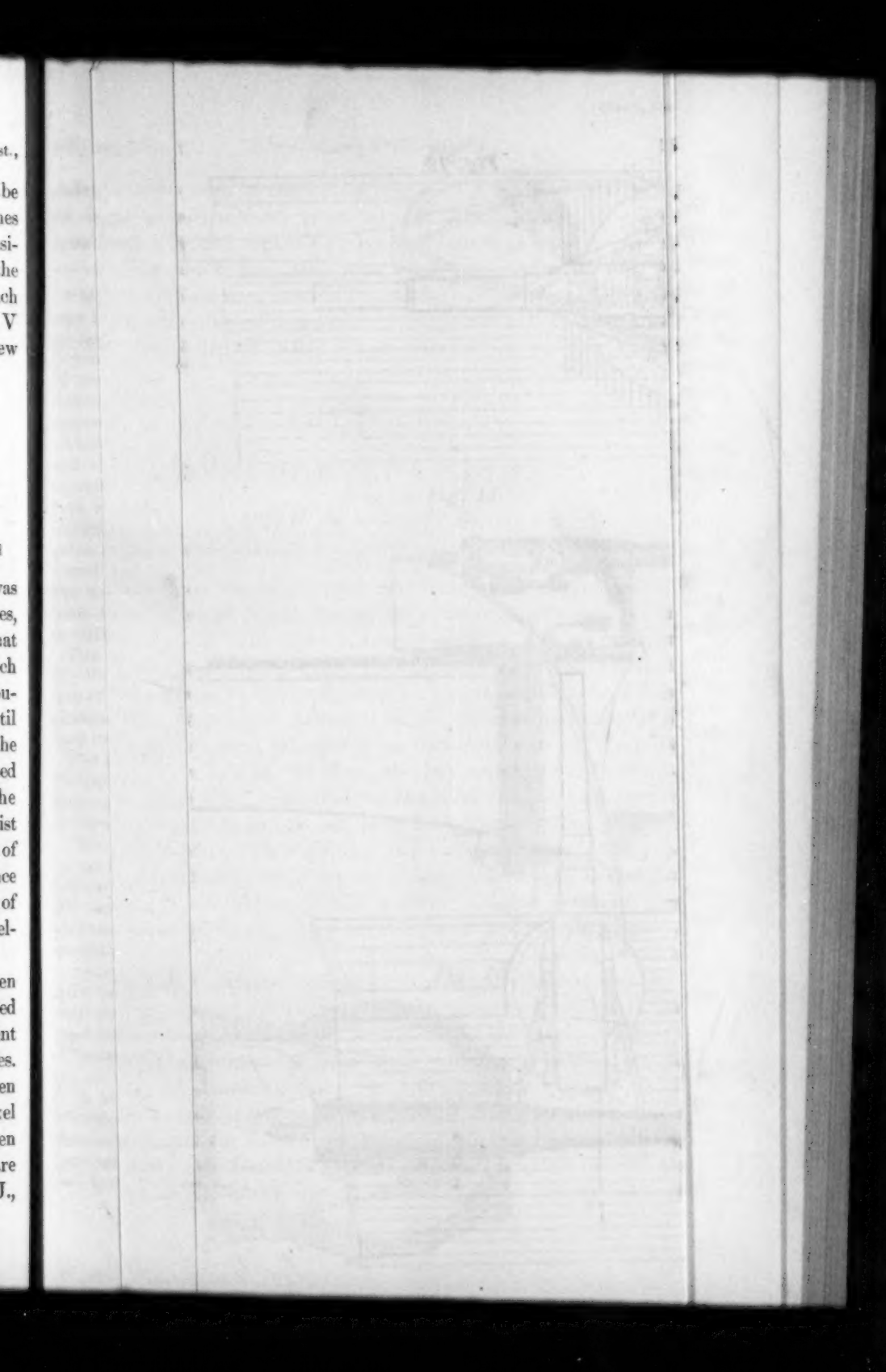


Fig. 9.

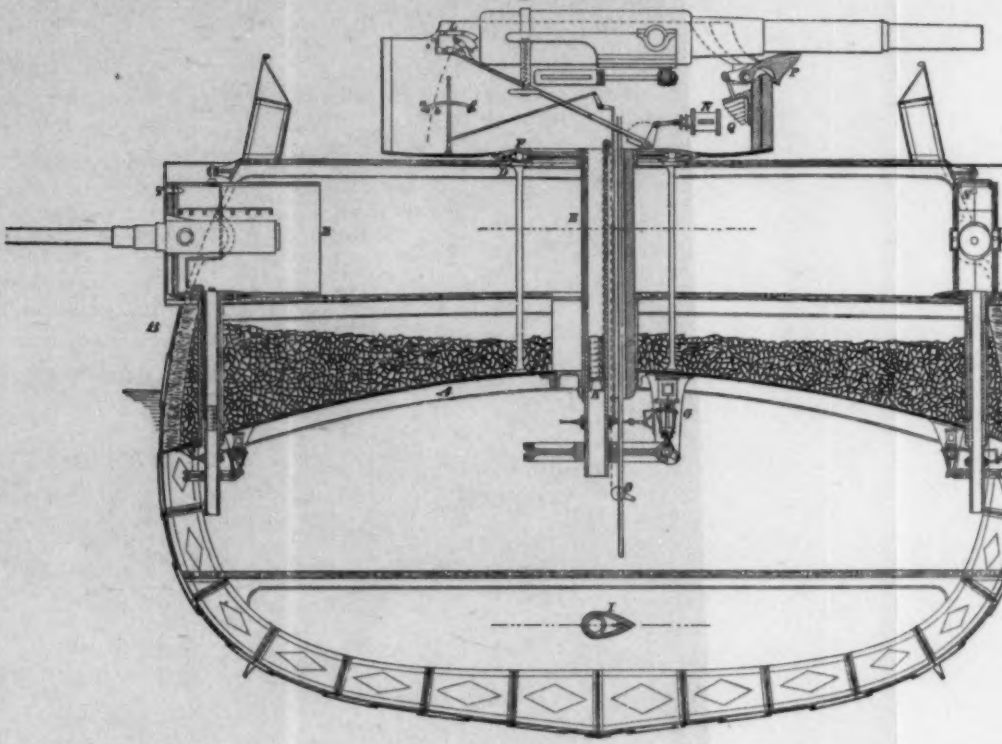
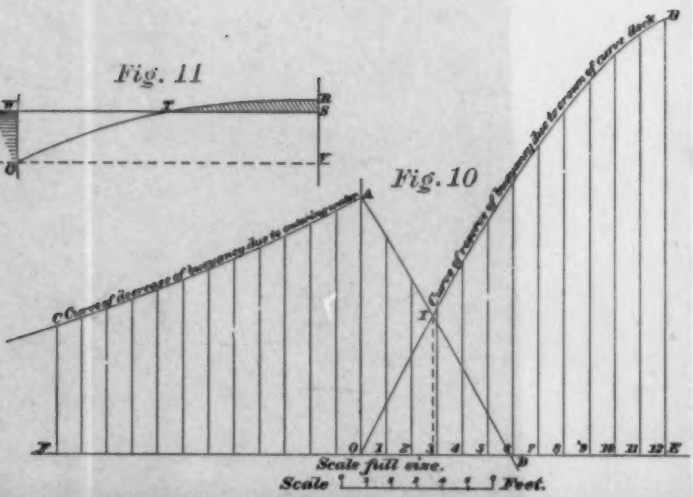


Fig. 11

Fig. 10



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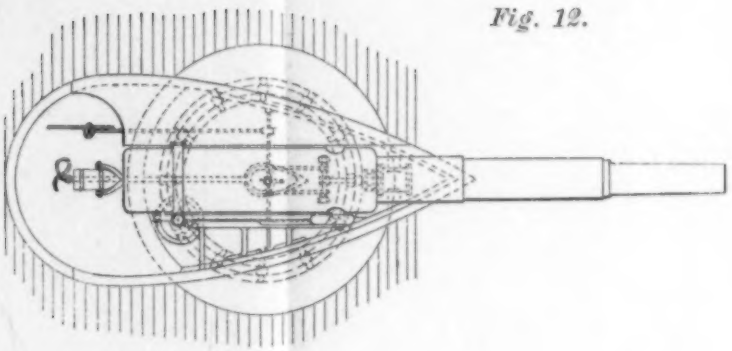
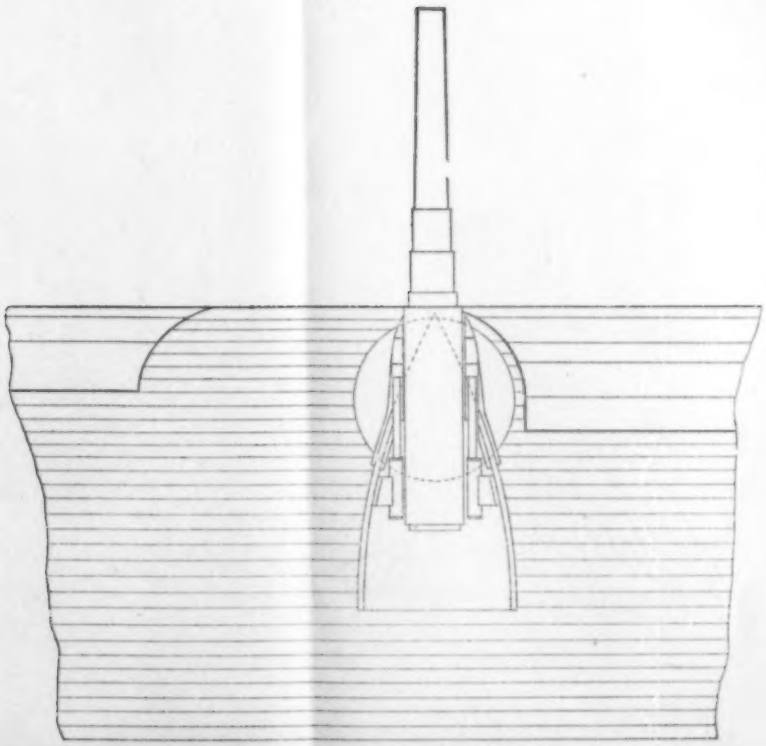


Fig. 13.



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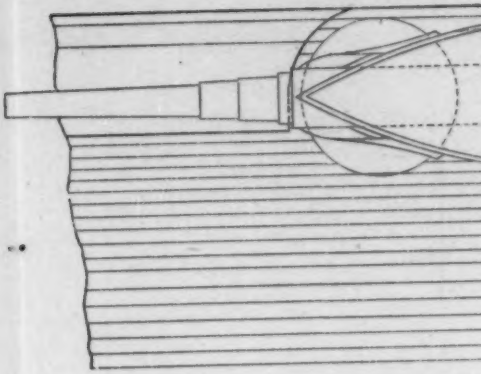

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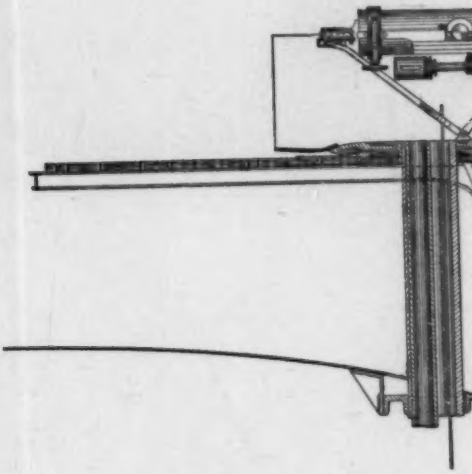

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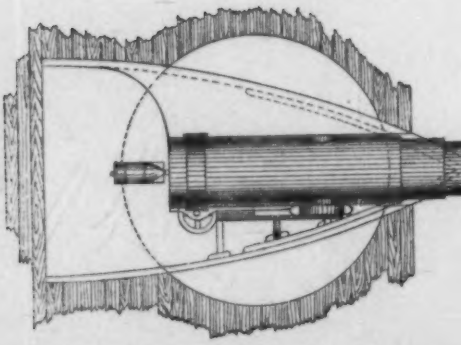

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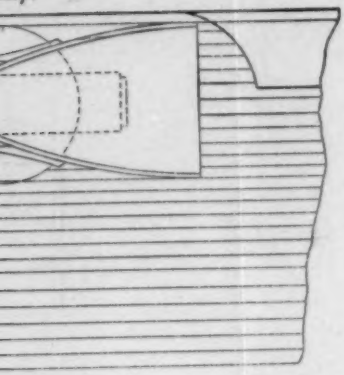

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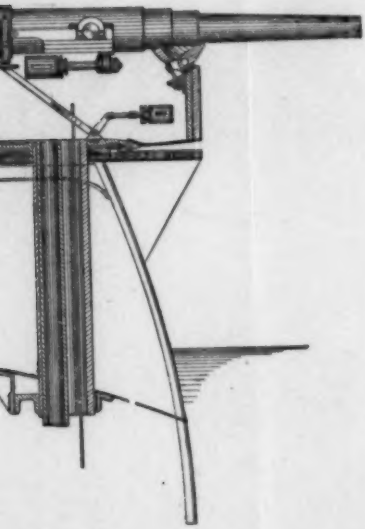

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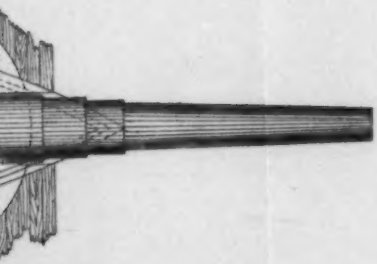

Plan of the Hussar (Showing Axis by Shot).

Fig. 44.

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under the scientific management of Mr. Joseph Wharton: * and second, the introduction and great improvement within this period, of the dynamo-electric machine, which placed at the disposal of electro-

* Mr. Wharton has produced at his works in Camden, N. J., since the year 1876, to the close of the year 1882, 1,466,765 pounds of metallic nickel. He began experimenting very early to determine whether nickel could not be produced in a pure and malleable condition, susceptible of being worked in nearly the same manner as iron, and of being applied in the manufacture of various objects demanding a strong, non-oxidizable metal. He succeeded so well that he was enabled to display at the International Exhibition in Vienna, in 1873, a sample of nickel in the form of axles and axle-bearings; and at the Philadelphia Exhibiton, three years later, he exhibited a remarkable series of objects made of *wrought nickel*, such as bars, rods, etc. These objects from their unpretentious character did not attract the attention they deserved. As a matter of justice to this indefatigable and intelligent worker, the fact should be placed on permanent record that he had succeeded as early as the year 1873, and with the lean and sulphuretted ores of Lancaster Gap, Pennsylvania, which yield only from 1½ to 2 per cent. of nickel, in producing the metal in malleable condition.

The recent discovery of pure carbonated and oxidized ores of nickel in the French colony of New Caledonia, has greatly stimulated the production of this metal and lessened its price; and the highly ingenious refining process recently discovered by Dr. Fleitmann, which is now altogether used in the production of the pure metal, has tended in the same direction.

The subject is of such interest that I quote the following brief account of Fleitmann's process, from a paper read before the American Institute of Mining Engineers at their meeting in Boston, in 1882, by Prof, W. P. Blake, of New Haven, viz:

"Dr. Fleitmann, of Iserlohn, Westphalia, Prussia, has improved and cheapened the operation of refining nickel and toughening it, and has reduced the liability to the presence of blow-holes in castings by adding to the molten charge, in the pot, when ready to pour, a very small quantity of magnesium. This is immediately decomposed, magnesia is formed, and graphite is separated. It would seem that the magnesium decomposes the occluded carbonic oxide, or reduces it to a minimum. The magnesium must be added with great care, and in small portions, as it unites explosively with the charge. It is stirred in. About one ounce of magnesium is sufficient for 60 pounds of nickel. From three-quarters of an ounce to 54 pounds of metal have been used with success by Mr. Wharton. The nickel from the ore at Lancaster Gap seems not to require as much as the foreign metal. It is to be noted that complete malleability of nickel was obtained at Wharton's works in Camden, before Fleitmann's invention or process, but this last is more rapid and better than the old method. The metal so treated becomes remarkably tough and malleable, and may be rolled into sheets and draw into wire. Cast plates can be successfully rolled. The cast plates,

platers a constant, powerful, and cheap source of electricity, in the place of the uncertain, troublesome, and comparatively expensive voltaic battery, to the use of which they had of necessity been hitherto confined. Alex. Watt* was among the first, I believe, to call attention to these facts. He states for example that "the difficulty in obtaining pure nickel anodes of large surface, for many years checked the progress of this useful art, whilst the slow and uncertain action of the ordinary battery rendered it ill-suited to the deposition of this peculiar metal on the large scale;" again, "it is doubtful whether nickel-plating would ever have held a really high position in the arts, if the dynamo-electic machine had not been introduced;" and in another place: "Indeed, as we have said, it is doubtful if this branch of the art (*i. e.* nickel-plating) could even have been extenisvely pursued with advantage on a large scale, if battery power alone were available." In considering the subject of the present very extensive application of nickel-plating, therefore, the above facts and explanations should not be lost sight of. So general has the demand for nickel-plating grown to be, and so universally is it employed, that, for the sake of economy,

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such as are made for anodes, after reheating, are rolled down to the desired thickness. It is found that it is a great improvement to the nickel anode plates to roll them down. They dissolve with greater uniformity in the bath. Nickel so treated with magnesium has been rolled into sheets as thin as paper. Expensive works for rolling the metal have been erected by Mr. Wharton at Camden. There is already a train of 40-inch rolls, 18 inches in diameter, with annealing-ovens and gas-furnaces and their adjuncts, and a 90 horse-power engine. The largest sheet yet rolled at Camden is 72 inches long and 24 inches wide, of pure nickel.

"Dr. Fleitmann has also succeeded in welding sheet-nickel upon iron and steel plates, so as to coat them equally on each face with a layer of nickel. The quantity preferred by weight is $\frac{8}{10}$ iron and $\frac{2}{10}$ nickel, one-tenth of nickel being placed on each surface. To secure union, the iron or steel must be perfectly flat and clean. A pile is made with outer facings of sheet-iron, to protect the nickel from scaling. When the whole is heated to the proper degree, it is passed through the rolls. The two metals become so firmly united that they may afterward be rolled down two or three together, or separately, to the thinness desired."

Consult also, *Jour. Franklin Institute.* cxvi, 60, *et seq.*, Art. Notes on the Metallurgy of Nickel in the United States. By Wm. P. Blake, F.G.S.

Also *Galvanoplastic Manipulations.* By William H. Wahl, Ph.D., Philadelphia. H. C. Baird & Co., 1883.

* "*Electro-Metallurgy*, Practically Treated." By Alexander Watt, F.R.S.S.A. 7th Ed., 1880. p. 86, *et seq.*

hundreds of establishments throughout the United States engaged in the manufacture of the most miscellaneous articles of brass, copper, iron and steel have introduced the nickel-plating plant, and do their own plating. Furthermore, innumerable small articles of metal of trifling value are nickel-plated after a fashion, by the manufacturers, not to protect them from the action of corrosive agents, but simply to catch the eye of the purchaser and to make them sell. As may readily be imagined, this state of things has produced a severe competition among those engaged in the business of nickel-plating which, while it has had the effect of bringing down prices to extremly low figures, has incidentally also had the effect of causing a very general deterioration of its quality.

An enumeration of the great variety of products that are nickel-plated would be impossible; among them may be named dental and surgical instruments of every description, harness- and saddlery-trimmings, carriage-fittings, spoons and forks, locksmith's work, brass cocks and faucets, and the decorative metal-work of plumbing and sanitary wares, scale- and balance-beams and weights, mountings of guns and pistols, the metal parts of lamps and lanterns, fire grates and fixtures, stove decorations, door-plates, cuspadores, watch- and clock-cases, hand-rails of railway cars and car-seats, etc., stair rods, points of lightning rods, show-cases, the external parts of sewing machines, steam and water valves, gauges, and miscellaneous machinery accessories without number.

From the very brief account that M. Roseleur gives of this subject, it would appear that the art of nickel-plating had received little or no attention in France up to the year 1880;* furthermore from the somewhat contemptuous reference with which he dismisses it, it is apparent that at that time he had no knowledge of the remarkable progress and development of the art in this country, and no conception either of the perfection to which the processes had been brought, or the beauty and utility of the results obtained.

Although, however, it would appear from the remarks of the author, just referred to, that nickel-plating had received but little attention in France up to the year 1880, the art appears to have been transplanted to England with much success, as the following reference to the subject

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* *Manipulations Hydroplastiques*, etc.; *par* Alfred Roseleur. 4e. Ed. Paris, 1880, p. 300.

by Watt* will testify: "the time has now arrived, however, when it may be fairly stated that the art of nickel-plating has become, in proper hands, one of the most successful, and at the same time one of the most extensive branches of electro-deposition. For several years nickel-plating in this country (*i. e.* England) had been principally confined to some three or four houses. Now, however (1880), the process has been most extensively adopted in London and throughout the kingdom, as also in many foreign countries. There is no doubt that its extensive application in the United States acted as a stimulus to our own manufacturers, who have steadily, though tardily, recognized in nickel a most useful coating for certain kinds of metal work."

NICKEL SOLUTIONS.

One of the earliest allusions to the electro-deposition of nickel is that of M. Ruoltz† in the year 1841. The reference is as follows: "The same method, that is, the use of a solution of the double cyanide in water (prepared by dissolving the metallic oxides in cyanide of potassium), may be employed for coating other metals with copper, tin, cobalt, *nickel*, and zinc." In 1843 Smee‡ states that "metals may be covered with nickel by proceeding as in former cases. The solution to be used is the chloride of nickel with a nickel positive pole. The single battery process is to be preferred, but pure nickel, though *very brilliant*, is apt to be rather brittle. . . . It is best reduced by the compound battery process, with a platinum positive pole, though a nickel positive pole may be employed. When we employ either the nitrate or sulphate of nickel for electro-metallurgy, it is preferable to use the solution as strong as possible. Of the compounds of these salts with the alkalies, those with ammonia deserve the preference, and the ammonio-nitrate and the ammonio-sulphate may be used for the reduction of this rather troublesome metal." In the same year (1843), Dr. R. Bœttger§ published an interesting account of his experiments in plating with nickel from which I take the following quotations: "No salt of nickel or of platinum has yet been found well adapted to plating baser metals with nickel or platinum. Experience has taught that a

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* *Electro-Metallurgy*, p. 87, *et seq.*

† Ruoltz, *L'Institut*, Nr. 414, p. 410; also Berzelius *Jahresber.* xxii, p. 96.

‡ Smee, *Elements of Electro-Metallurgy*, 2d (Lond.) Ed, 1843. pp. 154, 219.

§ *Jour. f. prakt. Chem.*, xxx, p. 267, *et. seq.*

compound of cyanide of nickel with cyanide of potassium, according to the statement of Ruoltz, by no means attains the object, nor is the platinum salt recommended by him any better."

"From a long series of experiments expressly made on this point, I believe I have discovered, and can give the assurance that among all the salts of nickel none is so well adapted to plating, especially on copper or brass, as the ammonio-sulphate of nickel; at least, the cyanide of nickel and potassium recommended by Ruoltz is far inferior to it, even in a very long-continued, constant current. Sheet copper comes out of the solution of ammonio-sulphate of nickel almost *silver white* and *brilliant*. I have obtained in this manner, after the action of a moderately strong galvanic current for half an hour, a considerable deposit of nickel on copper, quite sufficient to deflect violently from the magnetic meredian, a magnetic needle suspended by a fibre of silk. A drop of common nitric acid on the nickel coating exhibited in a given time no sensible action on the subjacent metal, while sheet copper which had been allowed to remain in a gilding bath under the influence of the current for the same length of time, was almost instantly attacked by nitric acid. From this it may be inferred that the galvanically deposited nickel coats the copper more rapidly, adherently, and uniformly than gold similarly deposited." . . . . . .

"To prepare the salt of nickel here referred to, the impure nickel of commerce suffices completely. To this end, it is dissolved in nitric acid, a stream of sulphuretted-hydrogen is passed through the solution for some time in order to precipitate all copper and arsenic, and the filtered solution is then precipitated by carbonate of soda. The well-washed carbonate of nickel is dissolved in dilute sulphuric acid, and the solution is placed beneath a bell-glass over concentrated sulphuric acid, in order to obtain it crystallized. These crystals are pulverized, transferred to a suitable flask, and ammonia gradually poured over them, until sufficient has been added to dissolve them. The resulting fine, dark-blue solution, may be directly used for the purposes above named."

It may be proper to add, in this connection, that one of the uses suggested by Bœttger for his solution is for the preparation of pure sheet nickel.

In the fourth edition of his work Roseleur* affirms that as early as

* *Manipulations Hydroplastiques*, etc.; *par* Alfred Roseleur. Paris, 1880, p. 301.

the year 1849 he had succeeded in the establishment of M. Kraintz, at Grenelle, in obtaining on table-ware an excellent deposit of nickel of considerable thickness, with the use of the double sulphite of nickel and ammonium as the depositing solution.

The next important contribution to the art of depositing nickel by galvanic means is made by Mr. George Gore, who, in 1855, employed the double salts of nickel and ammonium, *i. e.*, the double chloride. In the edition of his work on *Electro-Metallurgy*, published in 1860 (Griffin & Co., London, 1860), he describes a method for the electro-deposition of nickel by means of a solution of the double chloride of nickel and ammonium.

In 1862, MM. Becquerel, *père et fils*, read before the French Academy a paper on the "Electro-Chemical Reduction of Nickel, etc.,"* from which I quote as follows: "Nickel, we operate with a solution of sulphate of nickel to which has been added caustic potassa, soda, or ammonia, preferably the latter alkali, to saturate the excess of acid. Sulphuric acid becoming free is saturated by oxide of nickel placed on the bottom of the vessel, or by adding alkali to the solution, ammonia by preference. At the end of a certain time we obtain a brilliant, white deposit with a slightly yellow tint. According to the moulds employed it may be obtained in cylinders, bars, or medals. They possess, like cobalt, magnetic polarity when taken out of the solution. The ammoniacal solution of the double sulphate of nickel and ammonium, and even that which is not ammoniacal, likewise furnish metallic nickel."

In 1869, Isaac Adams, Jr.,† of Boston, obtained a patent in the United States for an "Improvement in the Electro-Deposition of Nickel," in which he describes a method of preparing the double salts of nickel—the double sulphate of nickel and ammonium, and the double chloride of nickel and ammonium—by which the same are obtained free from certain impurities, to the presence of which, he claimed, the difficulties in the way of obtaining a satisfactory deposit of this metal by galvanic means were ascribable. He describes in his patent specification a method of preparing these two compounds in

* *Reduction electrochimique du cobalt, du nickel, de l'or, de l'argent et du platine*; par MM. Becquerel et Ed. Becquerel. *Comptes Rendus*, lv, p. 19, *et seq.*

† Consult U. S. Pat., No. 93,157, August 3, 1869; or British Pat. No. 31,251, October 28, 1869.

such a manner as to be free from the presence of potash, soda, lime, alumina, and nitric acid, and directs that the electro-deposition of nickel by means of either of these double salts must be done from a solution that is free from acid or alkaline reaction. He likewise claims as his invention a method of preparing the nickel plates to be used as anodes in the depositing cells, which consists in melting the nickel and combining it with iron, for the purpose of avoiding the bad effects produced by copper and arsenic when these are present as impurities in commercial nickel. The effect of the addition of iron to the nickel (the amount being the chemical equivalent of the copper and arsenic present), Mr. Adams affirms, is to prevent the deposition of the above named impurities with the nickel. Quoting from the specification, "the iron itself is almost wholly precipitated as a peroxide, and is not deposited with the nickel to a sufficient extent to injure the character of the deposit. Neither does it injuriously affect the solution. The effect of the iron upon the copper is either to prevent it from being dissolved, or, if dissolved, to immediately reduce it upon the anode where it forms a coating which may be reduced from time to time by scraping. The arsenic forms an insoluble précipitate with the persalt of iron."

Mr. Adams continues:

"Having prepared the solutions and anodes, as herein described, nickel may be readily deposited; but, in order to carry on the deposition continuously, it is necessary to observe certain precautions: First, the use of a battery of too high an intensity must be avoided. An intensity of two Smee cells is sufficient. A high intensity decomposes the solution and liberates free ammonia, thus rendering the solution alkaline, and impairing its value. Whenever the smell of free ammonia arises from the decomposing cell the operator may be certain that the solution is being injured. It is important that the depositing shall not be forced by the use of too strong a current. Second, it is important that great precaution should be used to prevent the introduction into the solution of even minute quantities of potash, soda, or nitric acid. When an article to be coated is cleaned in acid or alkaline water, or is introduced into it for any purpose, the greatest care must be taken to remove all traces of these substances before the article is introduced to the nickel solution, as the introduction of the most minute quantities of acids or alkalies will surely be injurious. It is important that the solution be kept free from all foreign substances,

but its purity from those above named is especially important. Third, the anode of the depositing cell should present a surface to the action of the solution somewhat larger than the surface upon which the deposit is being made, particularly in the double sulphate solution. The reason is that nickel dissolves so slowly, that if the exposed surface is not larger than the surface on which the deposit is made, the solution will not keep saturated. On the other hand, if the anode is very much larger than the positive pole it tends to give a deposit of black powder. Fourth, if zinc is to be coated it should first be coated with copper, as it is difficult to make nickel adhere to zinc, and there is danger that the zinc may be acted on and injure the solution.

"With solutions and anodes thus prepared and used, the deposition of nickel can be carried on continuously and almost as surely and certainly as the deposition of copper from the common sulphate solution, though the limits of the battery-power which may be used are narrower. The metal deposited is compact, cohesive, and tenacious. It may be deposited of nearly uniform thickness over any surface, however, large. The deposited metal is capable of being annealed by a heat below a low-red heat. It then becomes flexible, malleable, and ductile. The deposit may be made of any required thickness, either to furnish effectual protection to the metal on which it is deposited, or to be removed and used separately from the surface on which it may be deposited."

In the same year, but a few months earlier than the date of the patent above referred to, a patent had been granted to the same inventor for the use of a solution of the sulphite of nickel in a solution of sulphite or bisulphite of ammonium.* This solution is identical, apparently, with that which M. Roseleur claims† to have used as early as 1849, with excellent results, in the establishment of M. Kraintz at Grenelle, but which, as I glean from a *Notice supplémentaire sur le Nickelage*, which he has lately issued, he has discarded in favor of the double sulphate.

The Adams patents were the first on the subject of nickel-plating in the United States, and the rapid development of the art to the proportions of an important industry, which took place within a few years thereafter, gives color to the claim that Mr. Adams is entitled to

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* Consult U. S. Pat., No. 90,332, May 25, 1869.

† See *ante*.

the credit of being the originator of the art of nickel-plating. I have elsewhere pointed out that the true explanation of the remarkable growth of this art is to be found in the substantial improvements in the metallurgical treatment of nickel, by which anodes of any desired size, and of great purity, were placed at the service of the nickel-plater; and more especially in the invention and improvement of the dynamo-electric machine, which has made the nickel-plater independent of the uncertain and troublesome voltaic battery. Had it not been for the want of these two important elements of success in this branch of the galvanoplastic art, plating with nickel would unquestionably have been extensively practised, years before it actually assumed a position as a successful and popular industry.

It cannot be denied, however, that Mr. Adams, by directing the attention of technologists to the excellent qualities of the double salts of nickel and ammonium at a time when everything was ripe for the new industry, materially assisted in calling it into existence, and in assuring its commercial success.

The years immediately succeeding 1869 were very prolific of inventions relating to the art of nickel-plating, many of which, however, were comparatively valueless. I select for notice few that appear to have meritorious features.

In 1877, John Unwin* of Sheffield (England) devised an ingenious process of preparing the double salts of nickel and ammonium. This consists in preparing a strong solution of sulphate of ammonium, by dissolving the salt in hot water in the proportion of about 4 pounds of the salt to each gallon of water, then filtering if necessary, and allowing the liquid to become cool. The double sulphate of nickel and ammonium is obtained by adding this solution to one of the sulphate of nickel. The novelty of Mr. Unwin's process, however, resides in the fact that he does not stop the addition of the sulphate of ammonium when sufficient has been added to combine with all the sulphate of nickel present, but continues to add it in large excess, "I do this," says Mr. Unwin, "because I have discovered that the double sulphate of nickel and ammonia is far less soluble in the solution of sulphate of ammonia, than in pure water, so that it is precipitated from its solution in water on adding sulphate of ammonia. I therefore continue adding the solution of sulphate of ammonia, continuously stirring,

* Consult British Pat., No. 1,548, April 20, 1877.

until the liquid loses nearly all its color, by which time the double sulphate of nickel and ammonia will have been precipitated as a light-blue crystalline powder, which readily settles to the bottom of the vessel. I then pour off the liquid from the crystalline precipitate of double sulphate of nickel and ammonia and wash the latter quickly with a strong, cold solution of sulphate of ammonia as often as I consider necessary for its sufficient purification." By this procedure it will be perceived, the double salt of nickel and ammonium is thrown down in a pulverulent, granular condition, readily soluble in water, and therefore ready for use in the depositing vat, without waiting for the tedious process of crystallization.

In 1878, Edward Weston,* of Newark, N. J., noticing its favorable influence upon the electro-deposition of nickel, secured a patent for "the electro-deposition of nickel by means of a solution of the salts of nickel containing boric acid, either in its free or combined state. The nickel salts may be either single or double." Mr. Weston affirms that the presence of boric acid prevents the deposit of sub-salts upon the articles in the bath, which is apt to occur if the bath is not in proper working condition; he claims, furthermore, that its addition in either the free or combined state to a solution of nickel salts diminishes the liability to the evolution of hydrogen when the solution is used for the electro-deposition of nickel, and increases the rapidity of deposition, by permitting the use of a more intense current, and improves the character of the deposit by rendering it less brittle and increasing its adhesion.

(To be continued.)

A SUMMARY OF PROGRESS IN SCIENCE AND INDUSTRY, 1883.

[From the Report of the Secretary, January 16, 1884.]

The year just past, though a dull year, was by no means a bad one, since we have had many that were decidedly worse. It was a year of moderate prosperity, characterized chiefly, as it advanced, by a progressive tendency towards a restriction of the consumption of manufactured products, lower prices, and a reduction in wages.

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* Consult U. S. Pat., No. 211,071, December 17, 1878.

My immediate purpose, however, is to present a summary of the industrial progress of the year, and in the following *resumé*, which comprehends only the more important items, a number of matters of interest are considered.

The most noteworthy event of the past year in the field of engineering was the final completion and opening to traffic of the great suspension bridge between New York and Brooklyn, which is universally acknowledged to be one of the unique and most imposing bridge structures of the world. The work was commenced in 1870, and was consequently thirteen years under construction. So much has been said and written concerning this remarkable structure, that any details of its character and dimensions would be a needless repetition. It will suffice to say that it was formally opened to the public on the 24th of May, 1883.

Another notable engineering event was the completion and opening to traffic, during the past year, of a double-track railroad bridge over the Niagara river, about 300 feet above the well-known suspension bridge. The new structure spans a chasm 870 feet wide between the bluffs, and over 200 feet deep. As the stream at this point is a foaming torrent, rendering the construction of piers in the river, or of temporary supports, impossible, it became necessary to design a structure which would be self-supporting during erection; and, to attain this object, it was decided to adopt a bridge of the cantilever type. The structure consists of two steel towers, 132 feet $6\frac{1}{2}$ inches high, resting on stone piers 39 feet high. Each tower supports a cantilever 395 feet $2\frac{5}{16}$ inches long, the shore ends of which are anchored to the abutment masonry, while the river arms are connected by an intermediate span of 120 feet extending from their extremities. The total length of the bridge is 910 feet $4\frac{5}{8}$ inches between the centres of the anchorage piers, the clear span beeween the towers being 470 feet. The height from the surface of the water to the base of the rail is 239 feet. The work of erection occupied but a few months, and it was subjected on completion to a test of unusual severity. It is regarded by those best qualified to pass judgment, as a most successful and creditable piece of engineering. It was constructed to connect the lines of the New York Central and Michigan Central railroads.

Of engineering projects advanced during the past year, perhaps the most interesting to us, is the scheme for the construction of a subway under

Broadway, as a means of relieving the inconveniences resulting from the present overcrowded condition of that thoroughfare. The scheme contemplates a subway street with sidewalks for foot passengers, and railway tracks for passenger and freight traffic. It is proposed to support the upper street upon columns and girders, with arches between, over which the roadbed and pavement will be laid.

The practical completion of another Alpine tunnel, the Arlberg tunnel, in Austria, during the last year, attracted little attention, although its importance is sufficient to warrant special mention of the fact. It is intended to form part of a railway line from Innsbruck on the Tyrol to Bludenz, in the Austrian province of Vorarlberg. The new tunnel is 11,231 yards long. The work will have required, when vaulted and ready to receive the first locomotive, about four years to complete.

The African inland sea project, of which so much has been said and written for the past ten years, has been finally shown to be impracticable. The scheme as originally formulated and ably defended, was to convert the Desert of Sahara into a great arm of the ocean, not unlike the Gulf of Mexico, by which, it was argued, the climate of Northern Africa, and of the contiguous portions of Europe, would be greatly ameliorated, while incidentally great commercial advantages would follow, by thus practically opening the interior of Africa to the commerce of Europe. All this was based on the belief and assumption that the interior of the great desert was a vast natural depression—the bed of an ancient sea—into which the waters of the ocean could be emptied by the simple removal of a coast barrier of inconsiderable magnitude. It has been finally shown that no such basin exists in the interior of the Sahara, and that its principal area is above the level of the Atlantic ocean. Thus this magnificent project is proved to be chimerical.

Of other engineering projects mooted during the past year, I may instance that of a submarine tunnel beneath the Strait of Messina, to connect Italy and Sicily; and a similar scheme to connect Spain with the African coast by a tunnel beneath the Mediterranean sea, concerning neither of which, however, by reason of their magnitude and costliness, is there the slightest probability that they will be undertaken.

It may be of interest to notice incidentally that the endless wire-cable system of drawing street cars, as a substitute for horses, to which I referred in last year's summary, has continued to demonstrate its

feasibility. It has been considerably extended both in San Francisco and Chicago. In Philadelphia, an experimental line, laid down in 1882, proved the advantages of the system so satisfactorily that the projectors have considerably extended it. In Kansas City, a cable road, with duplicate cables and duplicate operating mechanism, to avoid delays or stoppage of traffic, should one of the cables suffer injury, is about to be put in operation.

The work upon the excavation of the interoceanic canal at Panama is reported to have been vigorously carried on during the past year, and the opinion is now generally entertained that the canal will be built in spite of the difficulties interposed by nature.

The English Channel tunnel project seems, for the time at least, to have been allowed to slumber.

I may note at this point, as a matter of incidental interest that the question of increasing the present facilities of the maritime canal at Suez was the subject of much discussion during the past year. The commercial intercourse of Europe with the East has of late been growing so rapidly that for some time past there have been serious complaints of the inadequacy of the present canal, and of the serious delays in the transit of vessels which the constantly increasing traffic through the canal entails. To meet this emergency, two plans have been proposed—namely, to build a second canal along a route substantially parallel to the existing canal, or to considerably enlarge the present canal. Though both of these alternatives have been freely discussed, and the inadequacy of the existing facilities is admitted, considerations of a political nature have thus far proved effectual in delaying action.

Though it is yet too early to obtain the exact figures of the production of iron and steel, we may safely accept the estimates of the Secretary of the American Iron and Steel Association as being approximately true. He estimates the production of pig iron for the past year to have been about equal to that of 1882, in which year it was 4,623,323 gross tons. The total rail production of 1883, according to the same authority, was probably 1,300,000 gross tons, of which about 1,200,000 tons were steel rails, and 100,000 tons were iron rails.

I am enabled, by the courtesy of Mr. Frederick E. Saward, editor of the *Coal Trade Journal*, to give the following estimate of the production of the year 1883. This estimate assumes the total production to have been 93,800,000 tons, divided as follows: anthracite, 31,300,-

000 tons; bituminous, 62,500,000 tons. This estimate exhibits an increase in the figures of total production of about 7,000,000 tons as compared with the ascertained production of 1882.

From the most reliable sources of information, it may be assumed that the amount of new railroad constructed during the year 1883 will make a total of about 6,000 miles. Compared with the extraordinary development of the year 1882, in which the enormous amount of about 11,000 miles were added to the railway systems of the country, the figures for 1883 appear small; but measured by the standard of previous years, it possesses large proportions, since it has only been exceeded in four years, namely, in 1882, 1881, 1880 and in 1872; but, with these exceptions, exceeds the record of all previous years. It was apparent at the close of the year 1882, and the opinion was expressed in my summary for that year, that the rate at which our railway systems was being extended was too rapid to last, and that a notable diminution in mileage was to be expected in the year 1883. The facts above stated have justified this opinion, and evidences are not wanting at this time to warrant the opinion that the present year will witness a still further decline. The most notable event in our railway history during the past year was the completion of the trans-continental line of the Northern Pacific Railroad; while north of our border the Canadian Pacific road was extended to the foot of the Rocky Mountains.

The public interest in the subject of electricity was quite as pronounced during the past year as at any previous time. In the field of electric lighting I have nothing of special interest to record, save to note its steady extension and growth in popularity; and to note the special interest in and attention given to the subject of underground conduits for electric conductors in the streets of our cities. In this direction substantial progress appears to have been made.

The most prominent invention in this department of science which was brought out during the past year, was that of Messrs Delaney and Callahan, of a multiplex system of telegraphy, which, should it realize but a fraction of that which is claimed for it, must work a profound revolution in the art of telegraphy. The system in question is based upon the establishment and maintenance of the practically perfect synchronous rotation of two cylinders—one at each end of the line—with the aid of which a single line wire is placed in communication at both ends simultaneously with corresponding operating instruments, and transferred from one set of such instruments to another, so rapidly

that the operators receiving or transmitting messages are not conscious of any interruption of the circuit. The devices by which the synchronism of the distributing cylinders is maintained are highly ingenious, and entirely automatic, and are affirmed to act so perfectly that for days at a time one instrument will not vary from another by more than the one-600th of a second. Up to the present time the remarkable result has been accomplished, of developing seventy-two separate and independent circuits, adapted to printing telegraph instruments, simultaneously on a single wire, whereby thirty-six different messages may be sent each way, or seventy-two in one direction, or any proportion of this number in either direction, simultaneously over the same wire. The system has been subjected to careful tests, and has secured the unqualified praise of some of our most competent electricians. It is sincerely to be hoped that these flattering commendations may not prove to have been hastily pronounced, by the discovery of some unobserved element of impracticability. Should they prove to be fully justified, the era of cheap telegraphy is at hand.

The remarks of Mr. Weldon, in an address delivered last year before the Society of Chemical Industry in England, would seem to place beyond question the important fact, that the ammonia-soda process is destined to be the process of the future. It has not only made great strides in production in Continental Europe, where at the present time more than half the soda produced is ammonia-soda; but it has even invaded England, the last and greatest strong-hold of the Leblanc soda makers. From 2,500 tons in 1875, the production in England of ammonia-soda had risen to 50,000 tons in 1882, and is steadily on the increase. I have not at hand the figures exhibiting the total production of soda by the two rival processes, but it is an admitted fact that the outlook for the future of the Lablanc manufacturers is gloomy in the extreme, as the new process is not only making progress in England, but is rapidy growing in other countries, notably in Russia, Germany, Austria, and, as I had occasion to remark in last year's summary, in the United States.

The Leblanc soda makers have until lately consoled themselves with the belief that the limited supplies of ammonia—an important element of the newer process—would restrict the production of ammonia-soda. In this they have lately suffered a grevious disappointment, since the last year has witnessed the introduction of a practical procedure for obtaining ammonia in unlimited quantities at comparatively low cost.

The process here referred to, and which, by reason of its direct influence upon the production of soda, and of its ultimate great value to the agricultural interests in cheapening the price of fertilizers, may properly rank as the most important improvement in chemical technology that has lately been made, is neither more or less than the utilization of the ammonia evolved with the waste gases of the iron blast furnaces, and which has hitherto been lost to the chemical manufacturer. The method of ultilizing this ammonia consists simply in scrubbing the waste gases with sulphuric acid, or in fixing it by means of sulphurous or other gaseous acid, and washing out the ammonia salt with water. Several of the Scotch furnaces at which this method of treating their waste gases has been introduced, are said to be producing about a ton of crude sulphate of ammonia daily. From this statement it may readily be believed that in the probable event of the general adoption of the new procedure by the furnacemen of Great Britain, the yield of ammonia could be so enormously increased as not only to meet the demand for it by any possible expansion of the ammonia-soda process, but also to materially aid the agricultural interests, by cheapening the cost of this important fertilizing agent.

The belief gained currency during the past year, chiefly through what proved to be the mistaken opinion of certain eminent persons in England, that the important problem of the cheap production of aluminium had been solved by an English inventor. The publication of the process, unfortunately, dispelled the anticipations of those who have long looked in vain for the process which shall one day enable this metal to play the important role in the arts of civilization for which its valuable properties appear to have intended it.

During the past year much interest was attracted to the question of the availability of sorghum as a source of sugar, especially in view of the alleged adaptability of this plant to the northern States of the Union. The sorghum question has lately been exhaustively investigated by a Committee of the National Academy, which presented an encouraging report upon it, and an experiment upon a scale of considerable magnitude was last year put into full operation in our neighbor State of New Jersey. It is yet too early to pass judgment upon the merits of so important a question, and which involves the domestication of an agricultural industry, for the products of which the United States pays an annual tribute to foreign countries of about $80,000,000.

It is gratifying, however, to be able to record the continued success of the Alverado Beet Sugar Company in California, the only establishment in the United States at present engaged in the manufacture of beet sugar, and to which I made reference last year. The Alverado Company produced last year about 1,500,000 lbs. of beet sugar, and earned large dividends for its stockholders.

The success of this Company in the face of severe competition with the cane sugar of the Hawaiian Islands, which existing treaty provisions with that kingdom admit free of duty, is especially noteworthy. It effectually disposes of the notion that there is any insuperable obstacle in the way of the profitable introduction of this industry in the United States, and lends strong probability to the views entertained by those most competent to express an opinion, that the failures that have overtaken similar enterprises started in other States, were due to inadequate capital, incompetent management, or to both causes combined.

The energetic measures taken during the past year by Stanley and De Brazza, in their efforts to bring about a more direct commercial intercourse between Europe and the populous interior of the African continent, by establishing trading posts along the course of the river Congo, are worthy of special mention. Of interest, also, is the exploring expedition undertaken by Nordenskjold, to determine the character of the interior of the continent of Greenland. The results of this expedition, which have lately been published, though most disappointing to this indefatigable explorer, may be considered to have demonstrated the fact, that the vast interior of this hitherto unknown continent is a desert of perpetual ice.

A subject that should not be overlooked, because of its possible future industrial importance, is the discovery of tin ore in apparently considerable quantities in several localities in the United States, during the past year. Of these discoveries, one at least is so well authenticated that its value may be considered as placed beyond question. I refer to the announcement last year, by Prof. Wm. P. Blake, of the existence of ore desposits of this important metal of considerable extent in the region of the Black Hills of Dakotah. When it is considered that thus far not a single ton of tin is produced in the United States, and that we have imported tin plates alone to the value of $100,000,000, from England, during the past ten years, the importance

of developing domestic sources of supply of this indispensible metal, that promise to relieve the country of paying so large an annual tribute to foreign manufacturers, will be appreciated.

One of the most practical and far-reaching reforms introduced during the past year, was the adoption of a uniform system of standard time throughout the United States, and which has most satisfactorily done away with the annoyances and confusion arising from the almost innumerable local time standards hitherto in vogue. This reform, by almost unanimous concurrence of the government departments, municipal and town authorities, railroad companies and other influential corporations of the country, went into practical effect in the month of November, 1883. The plan of the new system, the suggestion and final adoption of which are due to Professors Abbé and Barnard, consists, briefly stated, in dividing the territory of the United States, which is comprised between the 50th and 130th degree of longitude west from Greenwich, into sections of 15 degrees each, and requiring all localities lying 7½ degrees east and west of the controlling meridian of that section to conform their time to that of this meridian. This arrangement not only introduces uniform time in each of the sections, but it makes the minutes and seconds on all the standard clocks identical, the hour hand alone showing a difference. The controlling meridians are the 60th, the 75th, the 90th, the 105th, and the 120th, giving to all localities lying within 7½ degrees east and west of each, respectively, its time; and the time of the five sections thus established is designated as Eastern, Atlantic, Valley, Mountain and Pacific time, and the standard time of the localities included in these sections differs by just one hour from that of its neighboring section—slower than that on its eastern border, and faster than that on its western border.

The past year will long be memorable in the United States as a year of floods of unprecedented magnitude, and of tornadoes of unparalleled violence. From both of these causes the destruction of life and property was very great. Other portions of the world were visited by siesmic disturbances of great energy and destructiveness, notably the islands of Ischia and Java. The outbreak in the latter island was attended with such destruction of life, and by such profound alterations of the topography of the country, and of the adjacent sea bottom, that competent authorities agree in pronouncing it to have been the most greatest disturbance of its kind that has occurred within the historic toric period.

PROPOSED ORDINANCE FOR THE EXAMINATION OF STEAM ENGINEERS.

At the stated meeting of the Franklin Institute, held Wednesday, October 17, 1883, Mr. J. W. Nystrom offered the following preamble and resolution, viz.:

To the President and Members of the Franklin Institute.

WHEREAS, The City of Philadelphia has suffered a great many disastrous steam boiler explosions which could have been prevented by proper precautions, and

WHEREAS, There are now in use in the City of Philadelphia some six hundred boilers which have dangerous flat cast iron heads, any one of which is liable to explode at any moment if in charge of incompetent attendants, and

WHEREAS, So great a number of dangerous steam boilers cannot reasonably be removed without great inconvenience and expense to the owners of these boilers, and

WHEREAS, It is known that the explosions of this class of boilers have been caused by incompetent attendants, be it

Resolved, That the Mayor and Select and Common Councils of the City of Philadelphia be respectfully requested by the Franklin Institute to pass an Ordinance to the following effect, viz.:

Supplement to an Ordinance of July 13, 1868, *entitled "An Ordinance regulating the Inspection of Steam Boilers in and for the City of Philadelphia, Pennsylvania.*

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That from and after the 1st day of January, 1884, all engines and steam boilers operated in the City of Philadelphia shall be run and in charge of such engineers only as shall be furnished with a proper certificate as hereinafter provided.

SEC. 2. The Chief City Inspector is hereby authorized and required to designate the time and place when and where all applicants for a certificate shall be entitled to apply for examination and shall receive a certificate if found to be competent. For this purpose the said Chief Inspector shall sit at least once a month.

SEC. 3. He shall issue certificates of two classes—the first to such parties as may in his judgment be qualified to have charge of an engine and boilers, the second, to such as may in his judgment be qualified to have charge of steam boilers in establishments where no engine is used.

SEC. 4. For these certificates, which shall be issued for one year, each party receiving the same shall pay a fee of two dollars for first-class, and of one dollar for second-class certificate.

SEC. 5. That the said City Inspector shall refuse to grant a certificate of inspection to any person who shall maintain or keep in use or operation, or shall put in use or operation, any stationary steam engine or boiler within the said City of Philadelphia, which shall not be in charge of an engineer duly furnished with an engineer's certificate as aforesaid.

SEC. 6. That whenever the said City Inspector shall learn of any boiler or engine being operated otherwise than by an engineer duly qualified and furnished with a certificate as aforesaid, he shall forthwith cancel and revoke his certificate of inspection. And the certificate of inspection of any steam-user who shall thus attempt to operate an engine or boiler without the care of an engineer furnished with a proper certificate shall be deemed and adjudged forfeited, and such steam-user shall be subject to all the pains and penalties provided by Act of Assembly of May 7, 1864.

JOHN W. NYSTROM.

On motion of Mr. Nystrom, the preamble and resolution were referred to a special committee. The President appointed Messrs. J. W. Nystrom, Washington Jones, C. M. Cresson, Coleman Sellers, Jr., Thomas Hockley, Esq.

In conformity with a resolution adopted at the stated meeting held November 21, 1883, the President increased the above-named committee by the addition of Messrs. William Helme and William A. Ingham.

At the stated meeting held December 19, 1883, the committee presented majority and minority reports, which were ordered to be printed for the use of members. In compliance with this order, the same are herewith submitted.

WILLIAM H. WAHL,
Secretary.

MAJORITY REPORT.

To the President and Members of the Franklin Institute.

GENTLEMEN:—Your Committee to whom was referred the resolutions relating to the "Examination and Licensing of Engineers by a

Board to be appointed by the City Authorities," presented at the meeting held October 17th, 1883, respectfully reports:

It is not advisable to ask for the passage of an ordinance requiring persons who have charge of engines to pass an examination and be licensed by a Board. Such an ordinance would be in restraint of liberty, and should never be enacted unless a free system is intolerable, or unless the reasons for restraint are shown to be overwhelming. Every security possible should be extended to life and property, but the undersigned are of the opinion that the proposed ordinance would not tend to increase it, for the following reasons:

First. The qualifications of an engineer, as to sobriety, watchfulness, application to his duties and a knowledge of the machine under his care cannot be determined by a Board of examiners, but can be, as now, by his employer.

Second. As the examinations must necessarily be upon the same few points, it might be possible for incompetent candidates to become possessed improperly of the correct answers to the questions, and consequently receive a license without possessing the qualifications of an engineer.

Third. The passage of such an ordinance would create a privileged class of men with power to fix their own wages regardless of the value of the service rendered, and, as proprietors, would be compelled by law to employ only those having a license, it would assist in extending an odious feature of Trades' Unionism.

Fourth. Should loss of life or damage to property be caused by an exploding boiler, whilst in charge of an engineer licensed by municipal authority, it is a question whether the responsibility would not be removed from the proprietor and placed upon the city.

Fifth. It is not within the scope of an Institution formed for the promotion of the Mechanic Arts to recommend or induce legislation upon matters not relating to its purpose.

Washington Jones,
Wm. Helme,
Coleman Sellers, Jr.,
Charles M. Cresson, M.D.

I concur in the above report except as to paragraphs, Nos. 4 and 5.

Thomas Hockley.

MINORITY REPORT.

PHILADELPHIA, Nov. 19, 1883.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Special Committee to whom was referred the preamble aud resolution in the matter of petitioning the Mayor and Councils of Philadelphia to pass an ordinance for examining stationary engineers and firemen, respectfully report

That the Committee is of the opinion that it would be of great advantage to the city of Philadelphia, as well as to steam-users therein, in regard to safety and economy in the working of stationary steam engines and steam boilers, to create a spirit of emulation among engineers and firemen, by classing them into grades by strict examination.

The Committee also believe that the examination of stationary engineers is of equal importance to that of steam boiler inspection and to the examination of steamboat engineers, and that it would be expedient to enforce strict examination of all stationary engineers in the State of Pennsylvania by an Act of Assembly.

According to the Census Report of 1883, there are 7,913 steam engines, aggregating 512,408 horse-power, in the State of Pennsylvania.

There are about 1,700 engineers in charge of stationary steam engines and steam boilers in the city of Philadelphia, of whom only 250 have certificates of competency.

The originally proposed ordinance, published in the November number of the JOURNAL, was found to be defective and incomplete for fully attaining its high purpose, and it has therefore been amended in hope that the Institute will approve its recommendation to the City Councils for adoption.

The City Councils have full power under the existing Acts of Assembly to pass the proposed ordinance, as will be seen by the following.

The Act of Assembly of May 7, 1864, for regulating steam boiler inspection, says on page 880 Pamphlet laws:

"SECTION 3. The Councils of the City of Philadelphia shall have power to make all needful rules and regulations for the purpose of carrying the foregoing provisions into effect, and shall provide such other regulations as may be nececssary to carry into effect the provisions of this Act and they may provide for the performance of the

duties, hereinbefore enjoined, by deputies, or other assistants of said inspector, as they may deem necessary."

This section makes it very clear that the proposed ordinance for examining engineers is one of "such other regulations" which is found to be necessary for carrying steam boiler inspection into effect. For, if the steam boiler is in charge of an incompetent attendant, the inspection is of no use, as has been proven by explosions of inspected boilers.

The City Councils have already passed an ordinance similar to the proposed one, namely, that of July 13, 1868, for regulating steam boiler inspection, which says, page 331:

"SECTION 11. If at any time the Inspector shall deem the engine-driver incompetent or unreliable, he may withhold or withdraw his certificate (of inspection). The inspector shall report to a magistrate and have bound over for trial any person or persons who may have rendered themselves liable by infraction of any provision of this ordinance, as provided in Section 4 of the Act of Assembly of May 7, 1864."

The question here arises, how can the Inspector find out if an engineer is incompetent without having first examined him? Or, is the Inspector to wait until the engineer has committed some blunders and caused steam boiler explosions with destruction of life and property, before considering him incompetent?

When the City Councils have power to pass the ordinance of July 13, 1868, with the Section 11, then they have also power to pass the proposed ordinance for examining engineers.

The Committee objects to the use of the term "engine-driver" as improper, for the reason that it is the steam which drives the engine, and not the engineer.

The question with the Franklin Institute in this matter is not that of law, which is for the City Councils to ask the City Solicitor, but whether or not it would be expedient for the City Councils to pass the proposed ordinance; for, in case they had not the power to pass it, such could readily be obtained by an Act of Assembly.

With the above considerations, the Committee respectfully recommends that the Franklin Institute shall take this forward step in the advancement of steam engineering, namely, to adopt this report, and submit it in full, with the preamble and resolution, to the City Councils, with recommendation for the passage of the proposed ordinance for examining stationary engineers.

JOHN W. NYSTROM, *Chairman.*

The following is the amended form of the proposed ordinance, referred to in the minority report:

PREAMBLE.

WHEREAS, The City of Philadelphia has suffered a great many disastrous steam boiler explosions which could have been prevented by proper precautions, and

WHEREAS, There are now in use in the City of Philadelphia some six hundred boilers which have dangerous flat cast iron heads, and other defects, and

WHEREAS, Any one of these boilers is liable to explode at any moment if in charge of incompetent attendants, and

WHEREAS, So great a number of dangerous steam boilers cannot reasonably be removed without great inconvenience and expense to the owners of these boilers, and

WHEREAS, It is known that the explosions of this class as well as of other classes of boilers have been caused by incompetent attendants, and

WHEREAS, It is of equal importance to examine stationary engineers as it is to examine steamboat engineers, for the reason that human life is as precious on land as on water, and

WHEREAS, It has been demonstrated by explosions that the object of steam boiler inspection cannot be rendered effective without competent attendants, and

WHEREAS, It has been proven by experience that it is necessary to examine steamboat engineers in order to render steam boiler inspection effective, and

WHEREAS, It would be of great advantage to the City of Philadelphia as well as to the steam users therein, in regard to safety and economy in the working of steam engines and boilers, to elevate stationary engineers by examination and grades, to the level of steamboat engineers, be it

Resolved, That the Mayor and City Councils of the City of Philadelphia be respectfully requested by the FRANKLIN INSTITUTE to pass an Ordinance to the following effect, viz.:

Supplement to an Ordinance of July 13, 1868, *entitled an Ordinance regulating the inspection of Steam Boilers in and for the City of Philadelphia, Pennsylvania.*

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain:* That from and after the first day of January, 1884, all Engineers and Firemen who have charge of stationary steam engines and steam boilers operated in the City of Philadelphia shall apply to the City Chief Boiler Inspector, for certificate of competency as hereinafter provided.

SECTION 2. The City Chief Boiler Inspector is hereby authorized and

required to designate a time and place when and where all applicants for certificate shall be entitled to apply for examination, and shall receive a certificate if found to be competent and of good standing. For this purpose the said Inspector shall sit at least once a month.

SECTION 3. That the said City Inspector shall have an assistant Examiner, whose duty shall also be to keep records of qualification and standing of each Stationary Engineer and Fireman who hold certificate of competency, and that each candidate shall be examined by both the said City Inspector and his assistant Examiner, and both to sign the certificate if found to be competent.

SECTION 4. That the said City Inspector shall issue certificates of five different classes, namely, as follows:

First Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working of engines and boilers for a term of not less than ten years, and can pass a thorough examination in the practical management and care of stationary steam engines and steam boilers; in the rudiments of the sciences involved in his profession, such as elements of mechanics; properties of water and steam in relation to heat; properties of different kinds of coal in relation to combustion and its economy; in the construction and properties of different kinds of stationary engines and boilers; in the properties and uses of steam indicators and indicator diagrams; and in the principal causes and prevention of steam boiler explosions. Any candidate who is found by examination to be worthy of a first class certificate shall be distinguished thereon as Chief Engineer.

Second Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working of stationary steam engines and steam boilers for a term of not less than five years, and can pass a thorough examination in the practical management and care of stationary steam engines and steam boilers, including the taking of, and working out indicator diagrams, and in the principal causes of steam boiler explosions.

Third Class Certificate shall be issued to any Stationary Engineer who has been continually in charge of the working and care of stationary steam engines and steam boilers for a term of not less than two years, and can pass a thorough examination in the practical management and care of such engines and boilers, and in the principal causes of steam boiler explosions.

Fourth Class Certificate shall be issued to any applicant whom the Examiners find competent to take charge of stationary steam engines and steam boilers of horse-power not exceeding that which shall be stated on the certificate.

Fifth Class Certificate shall be issued to any Fireman whom the Examiners find competent to take charge of stationary steam boilers used for heating purposes in manufacturing establishments where no steam engine is used.

SECTION 5. For these certificates each party receiving the same shall pay a fee as follows:

First Class Certificate, five dollars.

Second Class Certificate, four dollars.

Third Class Certificate, three dollars.

Fourth Class Certificate, two dollars.

Fifth Class Certificate, one dollar.

SECTION 6. All moneys collected as fees by said Inspector for aforesaid certificates shall be paid over to the City Treasurer, and the City Controller shall audit the accounts annually.

SECTION 7. That during the first six months of the year 1884, the time in which this Ordinance shall be brought into full effect, such Stationary Engineers and Firemen, who are well known to the said City Inspector, or to his assistant Inspectors or Examiner, to be competent and of good standing, may receive a third, fourth, or fifth class certificate without examination, but after the expiration of said six months, that is, on or after the first day of July, 1884, every applicant must be thoroughly examined as aforesaid, before receiving a certificate of competency.

SECTION 8. That on and after the first day of July, 1884, all stationary steam engines and steam boilers operated in the City of Philadelphia, shall be run and in charge of only such Stationary Engineers as shall be furnished with proper certificate of competency as before provided.

SECTION 9. That when any Engineer or Fireman who has received a certificate, is afterward found to be incompetent or negligent in his duty, the said City Inspector may cancel and revoke such certificate, and he may by re-examination issue to such Engineer or Fireman another certificate, but of a lower class to an Engineer.

SECTION 10. That the said City Inspector shall refuse to grant certificate of inspection to any party who shall maintain or keep in use or operation any stationary steam engine or steam boiler within said City of Philadelphia, which shall not be in charge of an Engineer duly furnished with a certificate of competency as aforesaid.

SECTION 11. That whenever the said City Inspector shall learn of any stationary steam engine or steam boiler being operated within the said City of Philadelphia otherwise than by an Engineer duly qualified and furnished with a certificate as aforesaid, he shall forthwith cancel and revoke his certificate of inspection.

SECTION 12. That the certificate of inspection held by any steam user who shall attempt to operate a steam engine or steam boiler without the care of an Engineer furnished with a proper certificate of competency shall be deemed and adjudged forfeited, and such steam user shall be subject to all the pains and penalties provided by the Act of Assembly of May 7, 1864.

SECTION 13. That nothing in this Ordinance shall be so construed as to render the City of Philadelphia responsible for any damage caused by steam boiler explosion or other accident occurring from neglect or incompetency of any Engineer or Fireman who may have passed his examination, and received a certificate of competency from the proper authorities.

SECTION 14. All Ordinances or parts of Ordinances inconsistant herewith are hereby repealed.

Celestial Photography.—The first application of photography to astronomy was made in France. The first Daguerrian image of a heavenly body was that of the sun, which was taken by Fizeau and Foucault, April 2, 1845. Soon afterwards fine photographs of the moon were obtained, in the United States by Rutherfurd, and in England by Warren de la Rue. In many observatories photographs of the sun have been taken for twenty years, to facilitate the study of the spots and faculæ. More recently still, Rutherfurd and Gould photographed the stars, for the purpose of forming celestial charts, and Draper obtained a successful photograph of the great nebulæ of Orion. The large solar images, which have been obtained during the last few years at Meudon, have revealed phenomena on the sun's surface which are invisible to the most powerful telescopes, and which open an entirely new field of research. By their aid we learn the true form of those elements of the photosphere about which so many different and contradictory assertions have been hazarded. In 1881, the first photograph of a comet with its tail was obtained at Meudon. It revealed curious details of structure and allowed divers photometric measurements, which showed that the tail, in spite of its apparent brilliancy, is from two to three hundred thousand times less luminous than the moon. The preservation of the images, the wide range of sensitiveness in the plates, and the faculty of embracing the most feeble as well as the most powerful luminous phenomena, lead Janssen to style the photographic plate the true retina of the savant.—*L'Astronomie*, April, '83.

Franklin Institute.

[*Proceedings of the Stated Meeting, Wednesday, January* 16, 1884.]

HALL OF THE INSTITUTE, Jan. 16, 1884.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

Present, 90 members and 5 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held Wednesday, January 9th, 11 persons had been elected to membership. He also presented the following

Annual Report of the Board of Managers for the year 1883.

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute during the year 1883.

During the year 139 new members have been elected; 22 have resigned; and 49 have been dropped for non-payment of dues.

The following is a condensed summary of the report of the Treasurer for the year ending December 31, 1883.

RECEIPTS.

Balance on hand, January 1, 1883	$ 1,931 65	
Cash received from Philadelphia and Reading Railroad bond ($1,000)	1,135 00	
Cash received from all other sources	13,844 99	
Total		$16,911 64

PAYMENTS.

Five per cent. Building Loan paid off	$ 136 25	
Six shares Pennsylvania Railroad stock	300 00	
Pennsylvania Railroad scrip bought to make even amounts to take 12 shares	44 46	
Exhibition of 1884	307 71	
All other current payments	15,465 65	
		$16,254 07
Balance on hand, December 31, 1883		657 57
Total		$16,911 64

The accounts show a diminution in cash balance of	$1,274 08
" " " securities of	251 75
Deficit for 1883	$1,525 83

Which is more than balanced by the increased value of the Library and other property of the Institute.

The increase of the Library during the year 1883, owing to the increased appropriation by the Board, aided very materially by the judicious activity of your Committee, has been greater than in any previous year, the total additions being over 3,000 volumes and pam-

phlets. The Board refers to the Report of the Committee on the Library for the details.

The Board feels impelled to repeat what has been said in previous reports, that the accommodations of the Library are entirely insufficient. New cases have been added and filled, and more ordered, but notwithstanding this, the Librarian is compelled to adopt the plan of doubling the volumes of scientific serials upon the shelves in the cases where they belong. The Board feels also compelled to denounce an evil, partly owing to present inconvenient arrangements which make it impossible for the guardian in charge to oversee the whole Library. It has been discovered that unprincipled persons have cut out pages and illustrations of books, and thus some of our sets have been mutilated, and it is impossible to know to what extent this has been done.

The progress of the JOURNAL has been satisfactory. The general index is far advanced, and is expected to be finished during the present year.

During the present year, thirty-five lectures were delivered under the direction of the Committee on Instruction, with the aid and counsel of the Professors. They were divided as follows: Prof. H. C. Lewis, two lectures on Geology; Mr. C. Henry Roney, four on Sanitary Engineering; Dr. H. F. Formad, five on the Smallest Living Organisms; Prof. A. J. Parker, five on the Sensory Organs; Dr. C. B. Dudley, two on Friction and Lubrication; Mr. Thos. H. McCollin, two on Photography; Prof. Persifor Frazer, two lectures introductory to the course on Chemistry; Prof. Coleman Sellers, one lecture introductory to the course on Mechanics; Mr. Joshua Rose, five lectures on Tools; Prof. W. H. Greene, four on Chemistry; Dr. C. Fahlberg, one on Technical Chemistry; Prof. E. J. Houston, a Christmas lecture to the children.

In addition to the above in the regular course, Mr. James Platt, of Gloucester, England, delivered, by invitation, a lecture on Hydraulic Machines as Applied to Riveting Boilers and Ships; and Edweard Muybridge, of San Francisco, one on the Attitudes of Animals in Motion.

The attendance at these lectures was uniformly good. The policy of issuing free tickets, to members for distribution to friends has been continued, and seems to give entire satisfaction.

The Drawing School, which still continues under the direction of Mr. William H. Thorne, has, in point of discipline, effectiveness of

instruction, and number of pupils in attendance, made gratifying progress.

The pupils in attendance at the spring term numbered 192, and those at the winter term, 184, making a total of 376. They were divided into seven classes with one instructor to each class. The school is now very efficiently organized and officered, and your Board refers to this branch of the Institute's work with satisfaction. The entire third story of the Institute building is now given up to the school, and its further growth will, therefore, be checked for want of additional class-rooms.

The last annual report of the Board contained a suggestion of a special Exhibition of Electricity and its applications. In execution of this design, the Board has caused all the necessary preliminary steps to be taken. In order to present the subject completely, it was decided to make the Exhibition international, and to that end a joint resolution of Congress was obtained to admit duty free all foreign contributions to the Exhibition. The free use of the lot at the corner of Thirty-second street and Lancaster avenue has been secured from the Pennsylvania Railroad Company, and the various sub-committees of the Committee on Exhibitions have completed the preparation of the papers to be issued both in this country and in Europe. The opening of the Exhibition has been fixed for Tuesday, September 2, 1884; and from the interest generally manifested in the subject, the Board has the confident hope that the Exhibition may prove of the greatest benefit to all concerned.

The American Association for the Advancement of Science has determined to hold its session for 1884 in this city during the month of September. The British Association, which is this year to hold its annual session in Montreal during the month of August, will then have adjourned, and it is hoped that a large number of scientific men may be in this city during the Exhibition.

To reap the full benefit of these circumstances, a committee was appointed by the Institute, at the September meeting, to arrange, if possible, for an Electrical Conference to convene in Philadelphia upon the occasion. This committee has been actively engaged in correspondence upon the subject, and has met with the cordial sympathy of distinguished men. A bill has been introduced into Congress, providing for the appointment of a National Scientific Commission to conduct the Electrical Conference, and appropriating a small sum to

defray the necessary expenses of conducting the investigations, reporting the proceedings, and publishing the results of the Conference.

The Board indulges the hope that this movement may be successful, and that so excellent an opportunity for the advancement of Science may not be thrown away.

The Chemical and Electrical Sections and the Phonetic Short-hand Section have exhibited a creditable degree of activity during the past year, and your Board refers to their reports with satisfaction.

The Committee on Science and the Arts, during the past year, has reported upon twenty-three applications, and in nine cases, has recommended the award of the John Scott Legacy Medal and Premium, all of which were confirmed by the Institute, and approved by the Board of City Trusts.

All of which is respectfully submitted.

By order of the Board,

W. P. TATHAM, *President.*

January 9, 1884.

The Committee on the Library presented the following Report:

Total number of volumes in Library, Dec. 30, 1882 (exclusive of pamphlets), as per last report, 16,776.

Additions in 1883.	Pamphlets.	Unbound.	Bound.
Bound volumes, purchased out of general appropriation			106
Unbound " " " "		43	
Pamphlets, " " "	80		
Bound volumes, purchased from JOURNAL			50
Pamphlets, " "	1		
Bound volumes (B. H. Moore fund)			111
Unbound " "		3	
Bound " donated			649
Unbound " "		203	
Pamphlets, "	1,398		
Exchanges for duplicates			139
Exchanges, bound in volumes			134
Volumes other than exchanges, bound			234
Rebound			3
Total	1,479	249	1,486

Total number of volumes in Library, Dec. 31, 1883, 18,262, exclusive of pamphlets, which (although no actual count has been made as yet) it is estimated, number about 9,000.

Of the books purchased, fifty volumes and one pamphlet, valued at about $110.00, were received from the JOURNAL of the Institute, to which they were sent for review.

Duplicates.—90 volumes and pamphlets, valued at $116.00, were exchanged for 139 volumes and pamphlets, valued at $128.00.

222 volumes and pamphlets have been presented to the Library by various Departments of the U. S. Government, and 95 (needed to fill gaps in serials) were purchased, at an expense of about $35.00.

Among the books presented are several volumes of American Ephemeris and Nautical Almanac (the publication office of which had omitted the name of our Library for the last two years); Reports of the Hayden Survey; Reports of Consuls upon the Commercial Relations with the United States (monthly publications, which will be sent regularly in the future); Reports of Director of U. S. Mint; Professional Papers of U. S. Signal Service (to be sent regularly in future); Navy Scientific Papers.

An exchange was effected with the U. S. Geological Survey Office for all future publications of that office, and the name of the Library placed on the distributing lists of a number of Bureaus in the Departments of the Government. During the last two months, correspondence has been opened with over 400 engineers and superintendents of water departments of cities of over 10,000 inhabitants for their reports, and your Library is now in possession of these. In many instances complete sets were obtained, which, for want of time to arrange, cannot be included in the list of serials completed during the year 1883.

Among donations received may also be mentioned, Dictionnaire des Jardinieres (deposited by Dr. A. J. Brazier in 1851, and presented to the Library by his sister, as per request of the deceased); a second invoice of books from the executor of the late John Lenthall, U. S. Navy, including the Transactions of the Institution of Naval Architects, with Index to first 21 volumes; Reed's Ship Building; Rankine's Ship Building, and many French works upon the same subject. Also, nine volumes of Poor's Railway Manual, valued at $45.00; ten volumes of Proceedings of American Pharmaceutical Association; a number of volumes of Journal of American Geographical Society,

from the Society; Journals of Select and Common Councils of Philadelphia, from Charles H. Banes; and Proceedings of the American Association for the Advancement of Science.

Exchanges.—108 foreign, 85 domestic and 20 city, or a total of 213 weekly, monthly and daily journals have been received in the Library during the past year in exchange for the JOURNAL of the Institute.

Serial Publications.—Sixty-one serial publications and four sets of scientific works have been completed during the year. Among them may be named: The Philosophical Magazine from 1796 (as Nicholson's Journal) to 1883, including all its branches; Newton's London Journal of Arts and Sciences; Transactions of Society of Arts, London; Journal of Society of Arts, London; Transactions of Institute of Naval Architecture of Great Britain; Proceedings of American Pharmaceutical Association; Canadian Naturalist and Geologist; Journal of American Geographical Society; American Association of Geologists and Naturalists; Civil Engineer and Architect's Journal, London; Reports on the Geology of Pennsylvania; Reports of Geological Survey of Kentucky, 1st series.

The accompanying table shows the additions of all kinds made to the Library each year since 1875, the date of the first published report:

Year.	Bound.	Unb. and Pamphlts.	Total.
1875	1,607	158	1,765
1876	1,448	408	1,856
1877	945	3,018	3,963
1878	455	351	806
1879	1,254	1,836	3,090
1880	566	843	1,409
1881	589	572	1,161
1882	808	478	1,286
1883	1,486	1,728	3,214
	9,158	9,392	18,550

Respectfully submitted.

CHAS. BULLOCK,

Ch'n Committee on Library.

The Trustee of the Pennsylvania Museum and School of Industrial Art presented the following Report:

To the President and Members of the Franklin Institute:

Your representative in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, herewith presents a summary of the operations of the Institution during the past year, viz.:

The number of admissions to the Museum in Memorial Hall, during the year was 168,931, being an increase of 9,648 over the year 1882.

The greatest number admitted in any one month was 30,465 in September, and the greatest number in one day was 4,323 on September 9th.

The steady increase in the number of visitors, which these figures exhibit, may safely be taken as an evidence of the growing popularity of the Institution.

The chief events in the history of the institution during the past year, are, the transfer to the Smithsonian Institution of the collection of the American Institute of Mining Engineers, the gift by Mrs. Bloomfield H. Moore, of eighty-two (82) large oil paintings (apparently old, and copies of old masters, but as no catalogue has been received to date, their authorship is unknown). The Museum made no purchases during the past year. One hundred and sixty-seven (167) objects were received by donation, and four hundred and thirty-seven were received on loan. The additions to the Library numbered twenty.

The School of Industrial Art, which is very properly regarded as the most important branch of the Institution's work, was continued during the past year at the rooms No. 1709 Chestnut street, under the same general direction as during 1882; the number of pupils averaged eighty-two (82).

The financial embarassments which for several years seriously hampered the proper development and usefulness of the Institution, were happily removed during the past year. By the active co-operation of the old Centennial Executive Committee of Women, under the name of the Associate Committee of Women, a very successful entertainment was given on December 12th, at the Academy of Music, for the benefit of the Endowment Fund, and which netted four thousand five hundred (4,500) dollars.

The Endowment Fund at present amounts to about fifty-five thou-

sand (55,000) dollars, all of which was definitively secured during the past year.

The Institution enters upon the present year with much ampler opportunities for usefulness than ever before.

Respectfully submitted,

WILLIAM H. WAHL.

Philadelphia, January 16, 1884.

Reports were also presented from the Chemical, Electrical and Phonetic Short-hand Sections.

All of the above were accepted.

The Tellers of the annual election held this day, between the hours of 4 and 8 P. M., made their report, whereupon the President announced the following as the result, viz.:

President (to serve one year), Wm. P. Tatham.

Vice-President (to serve three years), Charles Bullock.

Secretary (to serve one year), William H. Wahl.

Treasurer (to serve one year), Samuel Sartain.

Managers (to serve for three years), Washington Jones; Pliny E. Chace; Joseph M. Wilson; Coleman Sellers; Theo. D. Rand; A. E. Outerbridge, Jr.; Isaac Norris, M. D.; C. Chabot.

Manager (for one year in place of Wm. V. McKean, resigned), Chas. J. Shain.

Auditor (to serve three years), Lewis S. Ware.

Representative in the Pennsylvania Museum and School of Industrial Art (to serve one year), William H. Wahl.

A vote of thanks to the Tellers was unanimously passed.

The Secretary's Report embraced a *resumé* of progress in Science and Industry for the year 1883, published elsewhere in the JOURNAL; and a description of the following mechanical inventions, viz.:

An Improved Locomotive Headlight, of Post & Co., Cincinnati, in which the front glass is convex and provided with hinged transparent color signals, which, owing to the convexity of the front glass, can be seen from front, side or rear. The reflector is so pivoted as to permit its being turned through 90°, so that the lamp can be lighted from the side door instead of opening the front of the case. There is also a convenient match-striker. The lamp reservoir is removable for